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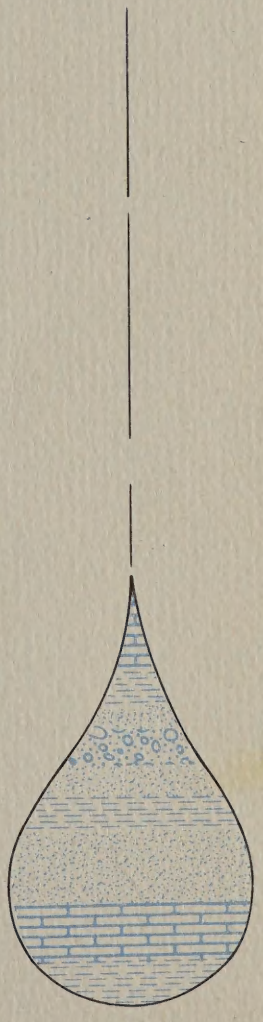
WATER-RESOURCES STUDY OF THE CARLSBAD POTASH AREA, NEW MEXICO

by

Geohydrology Associates, Inc.

for

BUREAU OF LAND MANAGEMENT
Denver, Colorado
Contract No. YA-512-CT8-195



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WATER-RESOURCES STUDY
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INTRODUCTION

In April 1978 the Bureau of Land Management (BLM) completed a preliminary study which defined the regional hydrologic conditions in the Clayton Basin and Nash Draw areas of Eddy County, New Mexico. This study was made by Geohydrology Associates, Inc., of Albuquerque under Contract No. YA-512-CT7-217. This study was based on file and literature searches and reconnaissance-type data collection in the field.

Earlier studies in the region established that the direction of ground-water flow was from northeast to southwest across eastern Eddy County. Most of the shallow ground water discharged into the Pecos River. However, in the vicinity of the potash refineries, ground-water flow patterns have been disrupted by various natural and man-made factors. Hydrologic parameters were not adequately known in the area.

Most of these previous studies provide insight to the existing hydrologic conditions in the vicinity of the potash refineries, but few were made in sufficient detail to identify brine sources. Robinson and Lang

(1938) showed that most of lower Nash Draw drained into the large, natural Salt Lake, and concluded that brine from the lake is not discharging into the Pecos River. Phreatophytes in the river valley have been identified as a source of damage to water quality that is unrelated to the potash industry (Thomas, 1963; Mower and others, 1964). Havens (1972) has shown that the aquifer beneath the river bed is a source of saline water in the Pecos.

A preliminary study by Gilkey and Stotelmeyer (1965) concluded that the brine-disposal ponds at the potash refineries leak significantly; whereas, industry spokesmen maintain that the ponds are sealed by fine sediments contributed from the tailings. The deterioration of water quality in stock and/or domestic wells has been documented (Geohhydrology Associates, Inc., 1978).

The Bureau of Land Management is the principal surface-management agency in the study area. As such, it has recognized its responsibility to define more accurately the brine distribution from industrial activities, evaluate industrial expansion plans, and document natural geologic and ground-water conditions. Therefore, the purpose of this study is to compile a summary report of the hydrology of the potash area.

The specific objectives to be addressed are as follows:

1. Establish the depth and configuration of the water table in the potash area.

2. Measure aquifer parameters in the potash area.

3. Refine the hydrologic parameters used in water-budget studies in order to establish more accurate inflow-outflow relationships at various plant sites.

4. Evaluate the suitability of several natural salt lakes as brine-disposal sites.

In order to fulfill these objectives, four specific approaches were used. A total of 27 test holes were drilled; most of these were tested to determine the hydrologic parameters of the water-bearing zones. Chemical analyses were made on selected water samples from test holes. These analyses were compared with chemical data collected previously. Detailed water-budget studies were made to define more accurately the amount of leakage from man-made retention structures. An observation well and rain gage network was maintained.

This report contains the findings of the investigation that was funded under BLM Contract No. YA-512-CT8-195. A description of the various techniques, analysis of the data, and the resultant conclusions are presented herein. Basic data collected during the course of this study is included in the Appendix of this report.

The system of numbering wells (and other data-collection points) used in this report is the same as that used in the Water Resources Division of the U. S. Geological Survey and the Office of the New Mexico State Engineer. It is based on the common subdivision of sectionized land. Each well is assigned a number divided into four segements (fig. 1). The first segment indicates the township south of the New Mexico base line. The second segment indiates the range east of the New Mexico principal meridian. The third segment indicates the section number within the township. The fourth segment of the well consists of three or more digits which indicate the particular 10-acre tract in which the well is located.

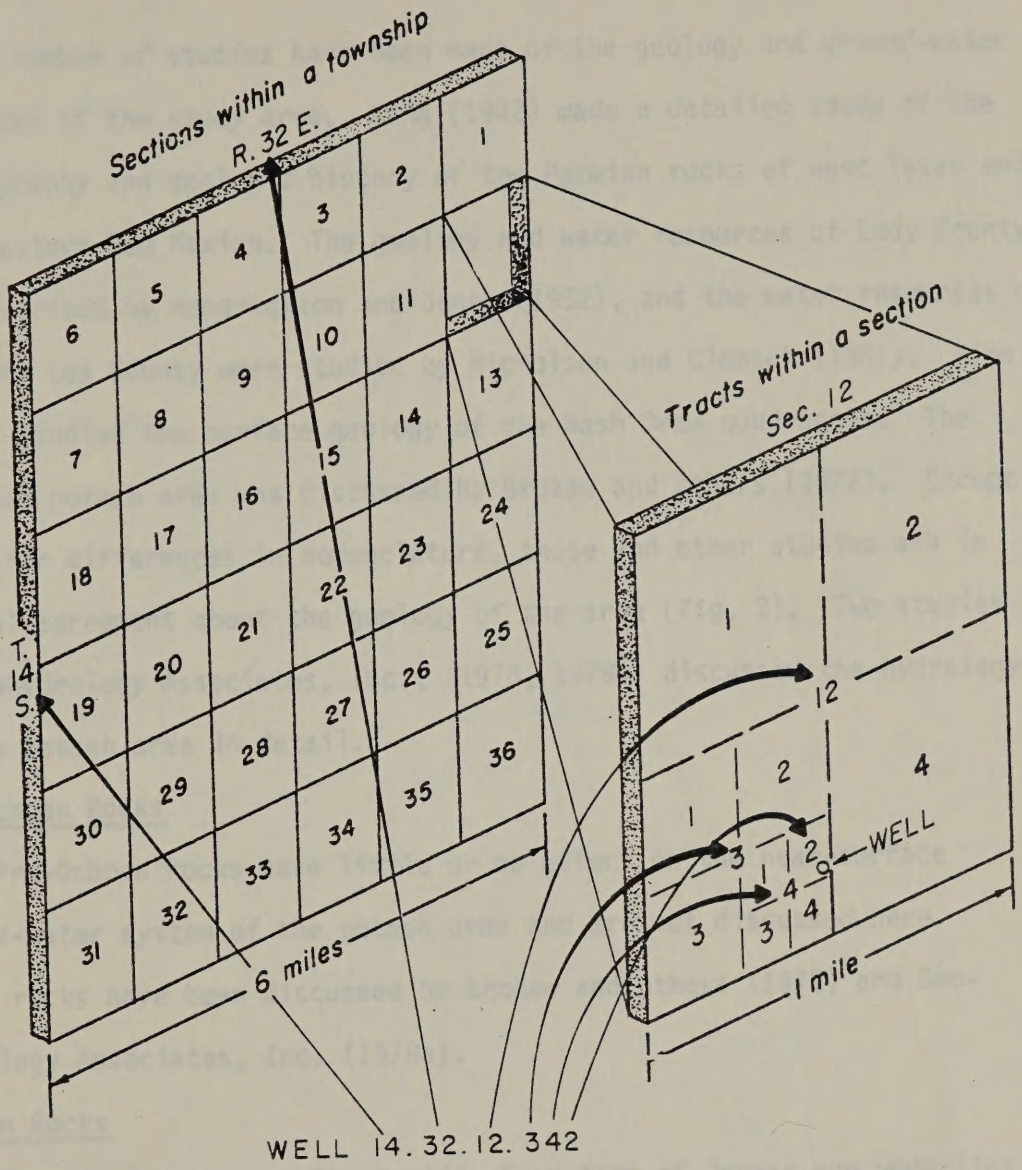
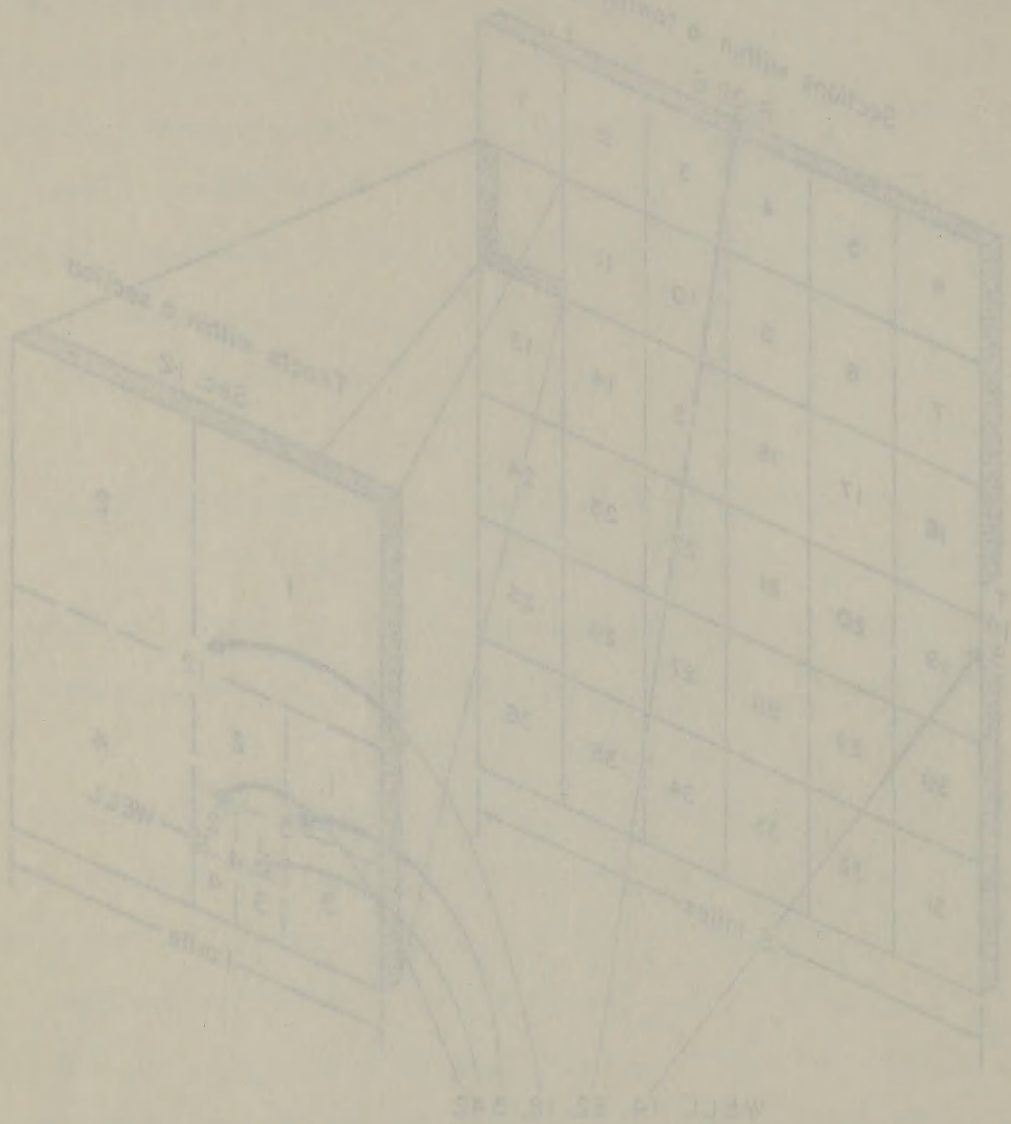


Figure 1. System of numbering wells in New Mexico.



GEOLOGY OF THE STUDY AREA

A number of studies have been made of the geology and ground-water resources of the study area. King (1942) made a detailed study of the stratigraphy and geologic history of the Permian rocks of west Texas and southeastern New Mexico. The geology and water resources of Eddy County were described by Hendrickson and Jones (1952), and the water resources of southern Lea County were studied by Nicholson and Clebsch (1961). Vine (1963) studied the surface geology of the Nash Draw quadrangle. The Carlsbad potash area was discussed by Brokaw and others (1972). Except for minor differences in nomenclature, these and other studies are in virtual agreement about the geology of the area (fig. 2). Two studies by Geohydrology Associates, Inc., (1978, 1978a) discussed the hydrology of the potash area in detail.

Pre-Ochoan Rocks

Pre-Ochoan rocks have little or no effect on the near-surface ground-water system of the potash area and are not discussed here. These rocks have been discussed by Brokaw and others (1972) and Geohydrology Associates, Inc. (1978a).

Ochoan Rocks

Castile Formation. The Castile Formation of Ochoan age underlies the study area. It is readily divided into three members: upper and lower anhydrite members and a thick middle salt member. In the north-central portion of the potash area, the salt member pinches out and the

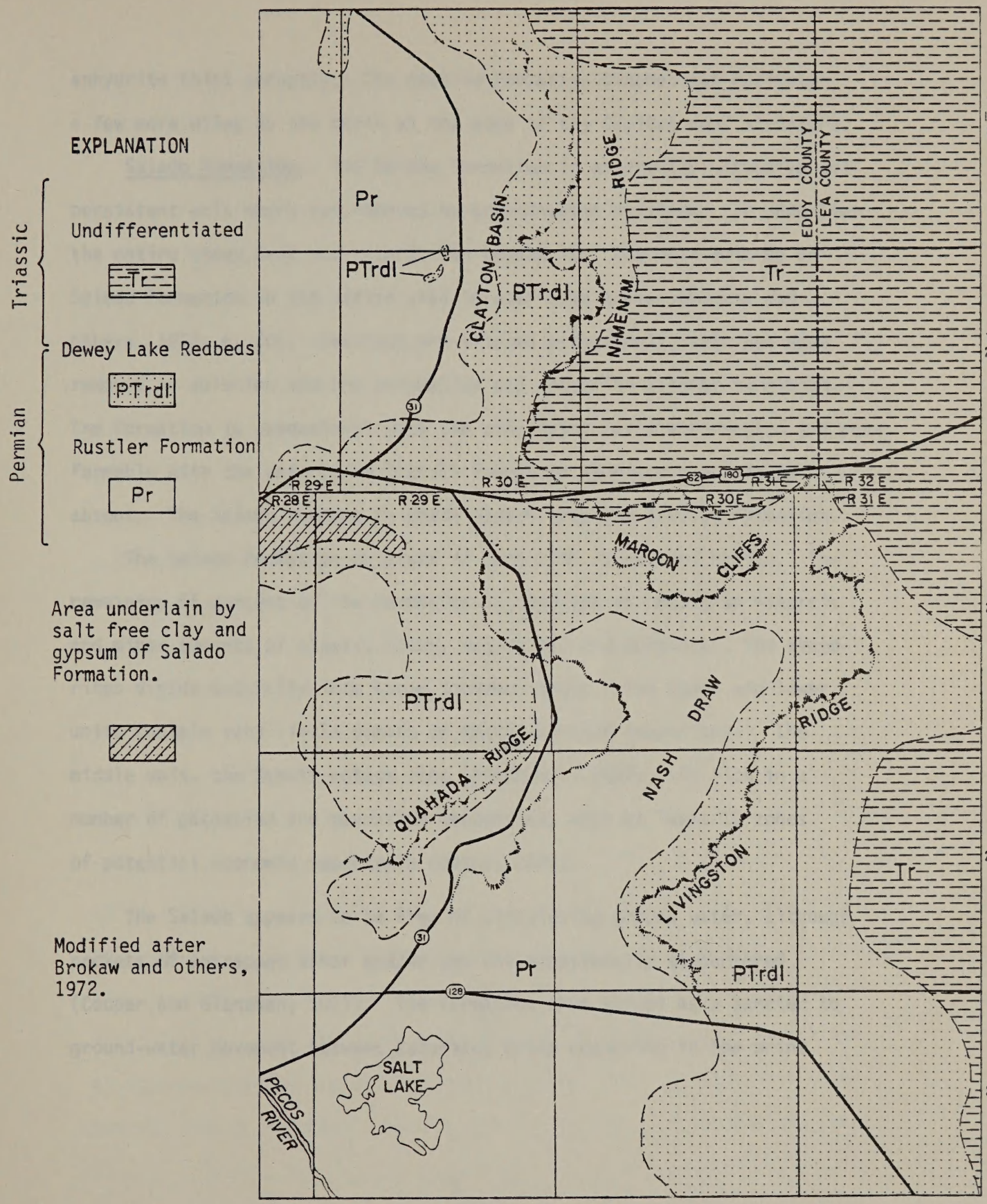
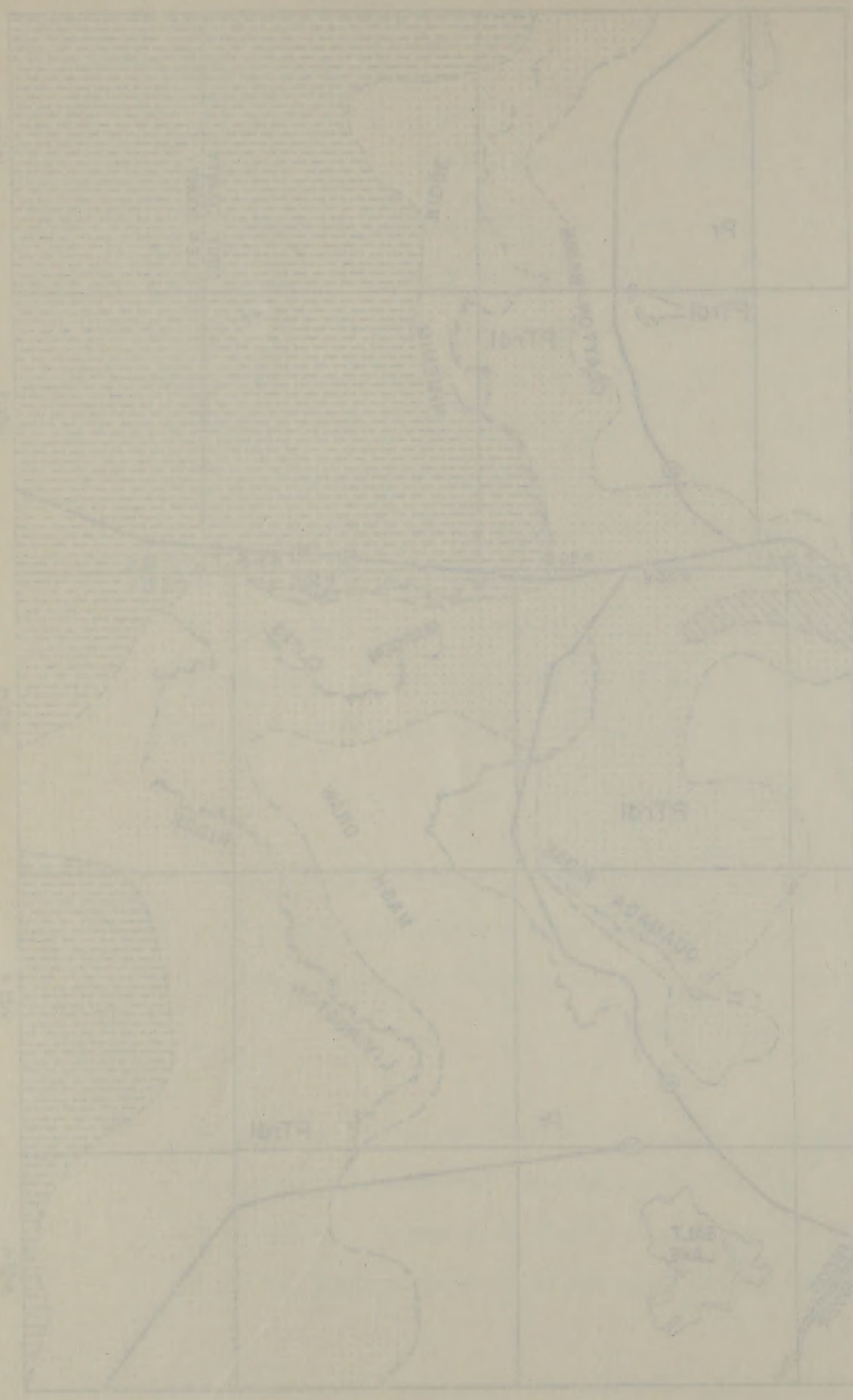


Figure 2. Geologic map of the study area showing distribution of Pre-Quaternary rocks, Carlsbad potash area.



anhydrite thins abruptly. The Castile Formation pinches out entirely a few more miles to the north at the edge of the Capitan reef structure.

Salado Formation. The Salado Formation is an areally extensive and persistent unit where not removed by ground-water solution. It underlies the entire study area and extends far beyond it. The main outcrop of Salado Formation in the potash area is near Lake Avalon (Brokaw and others, 1972, p. 40). Outcrops are altered extensively; salt has been removed by solution and the polyhalite and anhydrite altered to gypsum. The formation is gradational with the underlying Castile Formation and conformable with the underlying Tansill Formation wherever the Castile is absent. The Salado appears to grade upward into the Rustler Formation.

The Salado Formation consists of more than 75 percent halite. The remaining 25 percent of the formation is composed of potassium minerals and minor amounts of clastic rocks, anhydrite, and dolomite. The evaporites divide naturally into three informal units. The upper and lower units contain very little potash or magnesium-rich evaporites. The middle unit, the McNutt potash zone (Kroenlein, 1939), is rich in a number of potassium and magnesium evaporites, with at least 10 zones of potential economic importance (Jones, 1972).

The Salado appears to be free of circulating ground water, although pockets of entrapped water and/or gas are occasionally encountered (Cooper and Glanzman, 1971). The formation thus serves as a barrier to ground-water movement between saturated brine occurring in the brine

aquifer in the base of the Rustler Formation and less saline water beneath the Salado.

As a soluble unit underlying the entire potash area, the Salado exerts major control over the shallow and surficial structure of the area. Collapse structures, such as Nash Draw, are widespread and exert control over the deposition of eolian and alluvial material. Structure contours on the top of the Salado Formation show that the Nash Draw depression reflects a similar trough in the top of the salt (Vine, 1963, pl. 1). There are closed depressions in the top of the salt in the area of Salt Lake and Laguna Uno. The depth to the Salado Formation in the central part of the potash area ranges between 200 and 700 feet and increases northeastward and southeastward to about 1,300 feet (Brokaw and others, 1972, p. 42).

Rustler Formation. The Rustler Formation as originally described (Richardson, 1904) consisted of 150 to 200 feet of calcareous buff sandstone overlain by fine-textured white magnesian limestone. These units are thought to be equivalent only to the lower part of the Rustler Formation in the potash area where the formation ranges from 200 to 500 feet in thickness (Vine, 1963, p. 14; Brokaw and others, 1972, p. 51). Primary components in the Rustler Formation are gypsum and/or anhydrite, with dolomitic limestone, siltstone, and halite. Due to solution the halite does not crop out. The Rustler and Salado Formations are separated by a leached zone approximately 60 feet thick. This insoluble residue is regarded as basal Rustler Formation by some authors (Cooper and Glanzman, 1971) and as uppermost Salado Formation by others (Vine, 1963, p. 7). This water-bearing zone is commonly called "the brine aquifer." Robinson and Lang

(1938) estimated that this zone contains approximately 625,000 acre-feet of brine.

The removal of the Salado Formation in some areas has resulted in deformation of the over-lying Rustler Formation. The Rustler is topographically higher in areas where the Salado is still present and lower where the Salado has been removed. In general, the members of the Rustler Formation are lower in altitude within Nash Draw than on the edges of and outside the draw (fig. 3). In Nash Draw, the rocks of the Rustler Formation are frequently brecciated (Vine, 1963, pl. 1).

The lower member of the Rustler Formation consists of 60 to 120 feet of siltstone and fine-grained sandstone that intertongue with gypsum, anhydrite, and halite (Brokaw and others, 1972, p. 50). This lower member is overlain by the Culebra Dolomite Member, a distinctive and persistent marker bed about 30 feet thick. The Culebra Dolomite is a uniformly fine-textured microcrystalline gray dolomite or dolomitic limestone. It is characterized by the presence of many small spheroidal cavities from 1 to 10 mm (millimeters) in diameter, which apparently are unrelated to surface weathering (Vine, 1963, p. 14). Locally the Culebra is finely oolitic.

Outcrops of the Culebra Dolomite are present to the east and northeast of Salt Lake. In most of these outcrops, the dolomite is brecciated. Presumably most of Nash Draw is underlain at fairly shallow depths by Culebra rubble. The Culebra is an aquifer; water from the dolomite outside Nash Draw is relatively fresh.

The Culebra Member is overlain by the Tamarisk Member (Vine, 1963, p. 14) of the Rustler Formation. It consists of about 115 feet of massive, coarsely crystalline gypsum in outcrop but is chiefly anhydrite in the subsurface. There is a siltstone bed five feet thick about 20 feet above

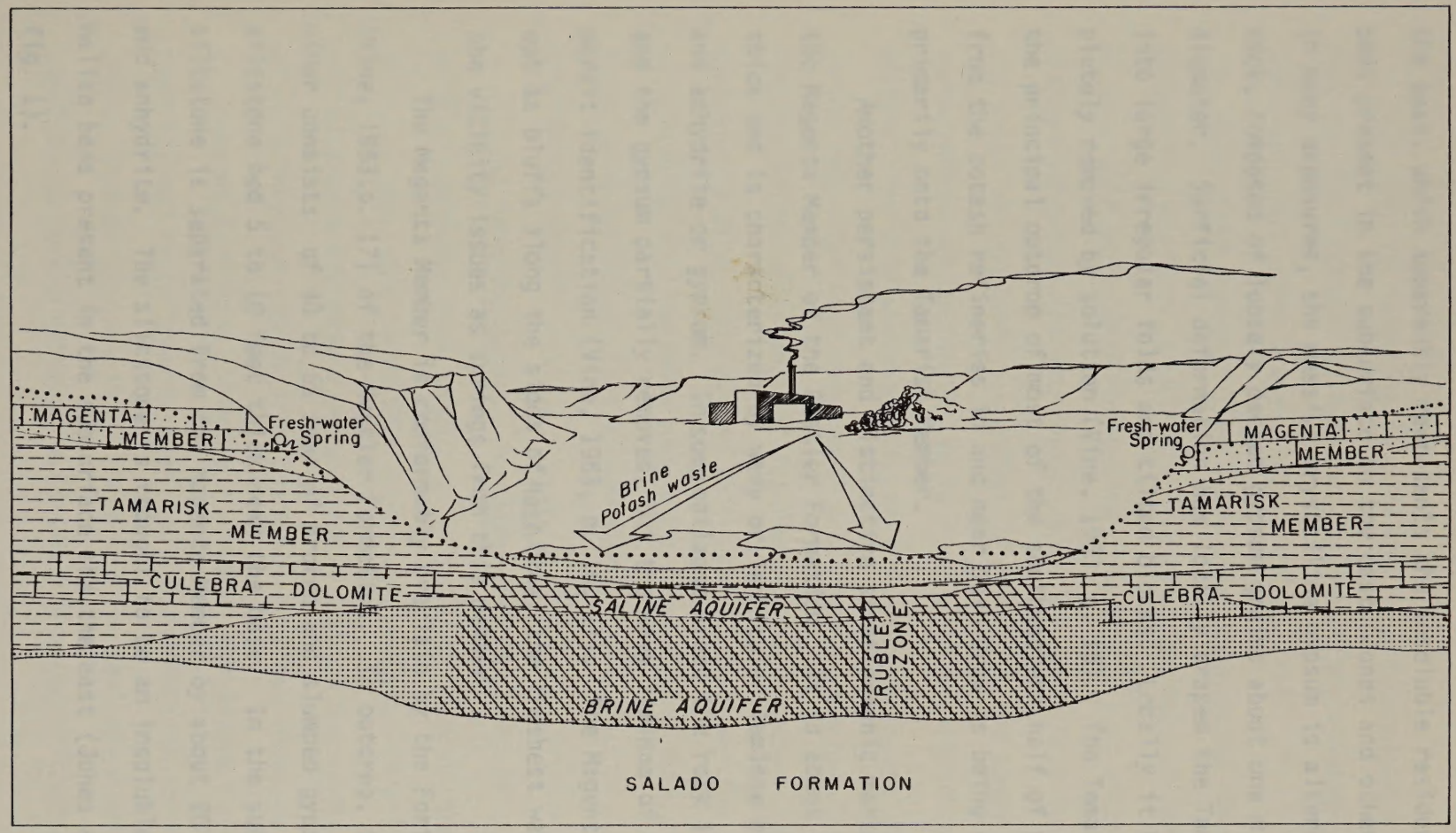
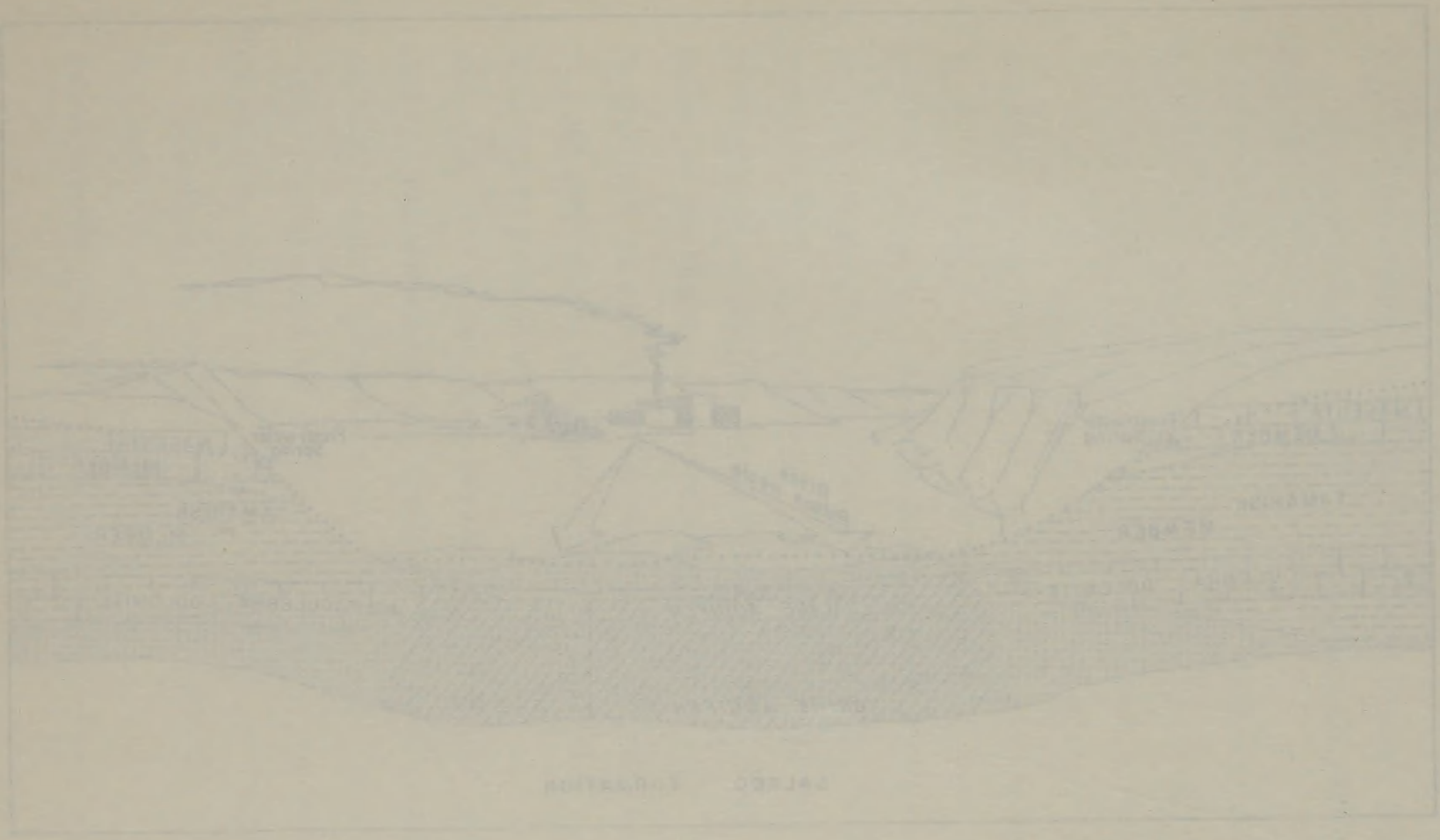


Figure 3. Diagrammatic east-west cross section through Nash Draw, showing stratigraphic units and ground-water relationships.



the base, which apparently represents the insoluble residue of halite beds present in the subsurface to the east (Jones and others, 1960, fig. 1). In many exposures, the massive crystalline gypsum is altered to gypsum rock, composed of loosely packed gypsum grains about one millimeter in diameter. Surficial deformation has locally draped the Tamarisk Member into large irregular folds and tilted blocks. Locally it has been completely removed by solution (Vine, 1963, p. 15). The Tamarisk Member is the principal outcrop of most of the southwestern half of Nash Draw. Brine from the potash refineries in and near Nash Draw is being deposited primarily onto the Tamarisk Member.

Another persistant and distinctive stratigraphic marker is the Magenta Member of the Rustler Formation. It is about 20 feet thick and is characterized by wavy or lenticular laminae of dolomite and anhydrite or gypsum. In some collapse areas the rock is brecciated and the gypsum partially removed, but the wavy laminae of dolomite still permit identification (Vine, 1963, p. 16, 17). The Magenta Member crops out as bluffs along the sides of Nash Draw; the freshest water found in the vicinity issues as springs from this member.

The Magenta Member is conformably overlain by the Forty-niner Member (Vine, 1963,p. 17) of the Rustler Formation. In outcrop, the Forty-niner consists of 40 to 65 feet of broken and slumped gypsum, with a siltstone bed 5 to 10 feet thick near the base. In the subsurface the siltstone is separated from the Magenta Member by about 20 feet of gypsum and anhydrite. The siltstone is thought to be an insoluble residue of halite beds present in the subsurface the the east (Jones and others, 1960, fig. 1).

The Rustler Formation is overlain by the Dewey Lake Redbeds. In outcrop, this contact is obscured by hydration, solution, and removal of the evaporites (Brokaw and others, 1972, p. 47).

Dewey Lake Redbeds. The Dewey Lake Redbeds are the only unit in the Ochoan Series which is entirely free of evaporites (Brokaw and others, 1972, p. 51). The Dewey Lake Redbeds consist entirely of siltstone and fine-grained sandstone and are 200 to about 500 feet thick in the study area. The rocks are exposed in a number of bluffs in the study area, especially in the region of Nash Draw, as in Mimosa and Livingston Ridges and Maroon Cliffs. The reddish-orange to reddish-brown sandstone and siltstone are thinly laminated with very small scale cross-laminae. Ripple marks are present in the upper part of the formation. Exposures of the Dewey Lake Redbeds are frequently draped into simple structures due to either solution of hydration or underlying evaporite rocks (Vine, 1963). Generally the Dewey Lake Redbeds is not an aquifer.

Post-Ochoan Rocks

Santa Rosa Sandstone. The Dewey Lake Redbeds is unconformably overlain by the Santa Rosa Sandstone in the study area (Brokaw and others, 1972, p. 52). The Santa Rosa Sandstone consists primarily of gray and red sandstone and conglomerate lenses, 3 to 15 feet thick, with partings of reddish-brown siltstone and claystone (Vine, 1963, p. 25).

Gatuna Formation. Wherever present, the Gatuna Formation of Pleistocene (?) age unconformably overlies the older rocks in the Carlsbad potash area. In most places, it is three to five feet thick and is directly overlain by Recent caliche, which provides protection from erosion (Vine,

1963, p. 27). The formation consists of reddish-brown to reddish-orange, poorly consolidated sandstone and siltstone, with smaller amounts of conglomerate, clay, and shale. It is locally up to 200 feet thick (Hendrickson and Jones, 1952). The substantial and rapid changes in thickness have led Vine (1963, p. 31) to conclude that deposition of the Gatuna accompanied or immediately followed a period of active solution of the Salado or Rustler Formations.

Caliche and Alluvium. A thin layer of caliche unconformably overlies the Gatuna Formation. It forms a fairly continuous, 10-foot thick, resistant mantle. Sinkholes in the caliche are a common result of solution of underlying gypsum. Mounds or ridges of caliche may result from a variety of causes, such as a thermal expansion or hydration of anhydrite to gypsum (Vine, 1963, p. 31.)

Structure

The basic tectonic structure of the Carlsbad potash area is a simple homoclinal dip of about two degrees to the east which is superimposed on the Delaware structural basin (Vine, 1963, p. 37). The more complex surficial structure of the potash area exerts a more immediate effect on the hydrology. The area is characterized by collapse of the Rustler Formation and overlying beds due to solution within the Rustler and at the top of the Salado Formation. Beds of the Rustler generally dip toward the larger depressions (Vine, 1963). In addition, hydration of anhydrite to gypsum causes localized doming. Sinkholes and domes influence the direction of ground-water movement, which in turn controls the development of collapse structures.

DRILLING AND AQUIFER-TESTING PROGRAM

In October and November 1978, 27 wells were drilled in the study area (fig. 4). The four primary objectives of the drilling and aquifer testing program were: to determine ground-water elevations in areas where data were lacking; to determine hydrologic properties of the water-bearing zones; to find out direction and rate of ground-water movement; and to establish a system of observation wells to monitor changes in ground-water elevation and quality. Wells were drilled to penetrate the water table to sufficient depth for testing. Specific aquifers were not selected.

Drilling Procedure

The test holes were drilled with an air-rotary rig using a 6-7/8-inch bit; cuttings were removed from the hole by air and foam. Samples were collected at 10-foot intervals as the drilling proceeded and analyzed on site. The lithologic logs are included in the Appendix of this report.

Depths range from 35 to 460 feet. Upon completion, 5-inch PVC pipe was set. A 20-foot length of pipe was perforated with ¼-inch holes and set opposite water-bearing zones. Holes were cased to total depth.

Electric logs were run on most of the test holes by the U. S. Geological Survey. Gamma, neutron, and density curves were made.

Testing Procedure

At the completion of drilling of each test hole, the well was bailed. This provided an approximation of the yield that could be expected and helped in selecting those wells that were suitable for testing.

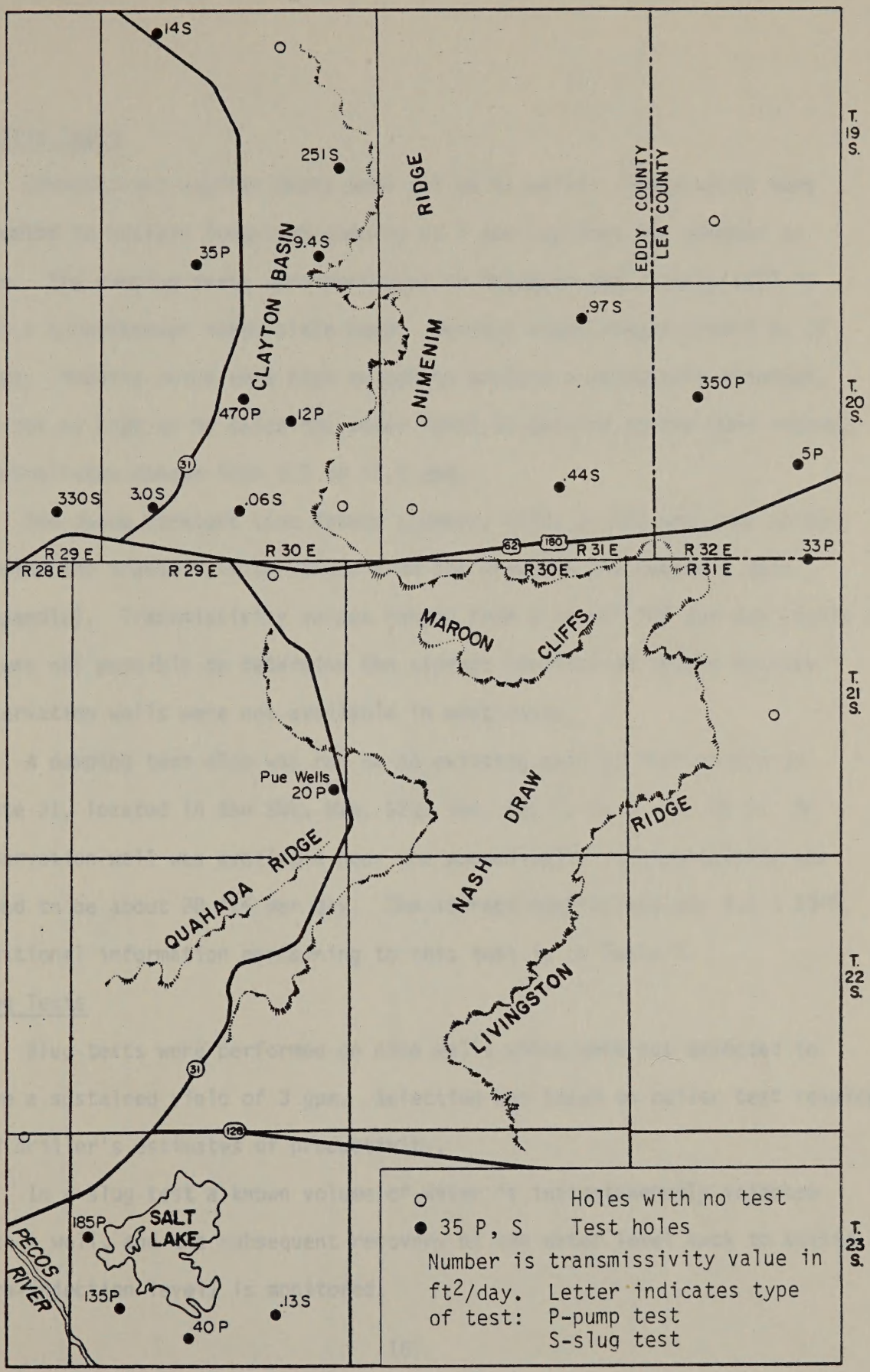
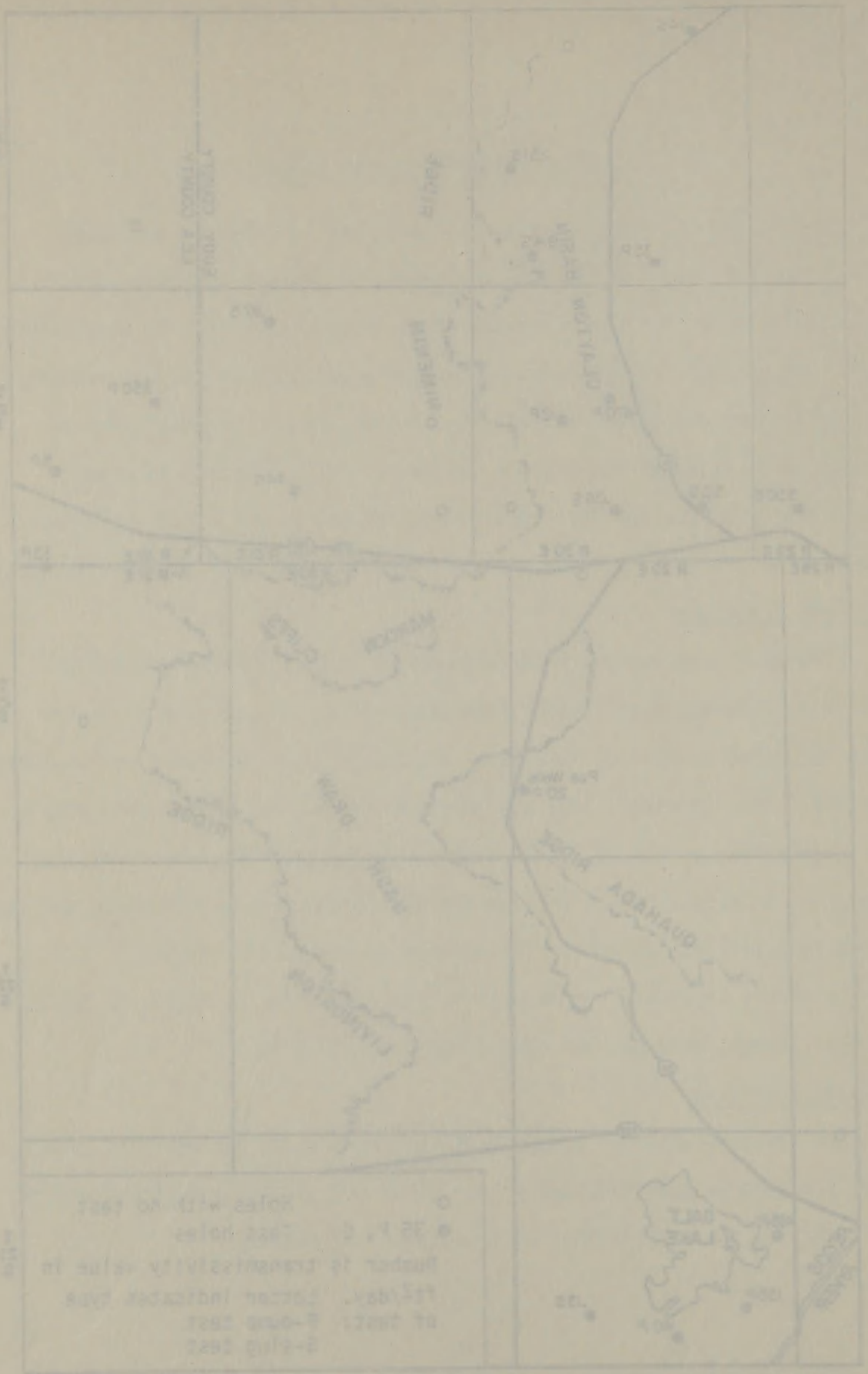


Figure 4. BLM test hole locations with selected transmissivity values in ft^2/day.



Aquifer Tests

Conventional aquifer tests were run on 11 wells. These wells were expected to sustain long-term pumping at 3 gpm (gallons per minute) or more. The pumping tests were performed in December and January 1978-79 with a ½-horsepower submersible pump. Pumping times ranged from 3 to 18 hours. Pumping rates were high enough to produce a measurable drawdown, but not so high as to cause the water level to decline to the pump intake. Pumping rates ranged from 3.5 to 17.6 gpm.

The Jacob Straight Line Method (Lohman, 1972, p. 23) was used to determine the transmissivity values from the drawdown and recovery data (appendix). Transmissivity values ranged from 5 to 470 ft^2 per day (table 1). It was not possible to determine the storage coefficient values because observation wells were not available in most cases.

A pumping test also was run on an existing well at Pue's Store on Route 31, located in the SW¼, NW¼, SE¼, sec. 25, T. 21 S., R. 29 E. An observation well was available near the pumped well. Transmissivity was found to be about 20 ft^2 per day. The storage coefficient was 9.6×10^{-6}. Additional information pertaining to this test is in Table 2.

Slug Tests

Slug tests were performed on nine wells which were not expected to have a sustained yield of 3 gpm. Selection was based on bailer test results and driller's estimates of productivity.

In a slug test a known volume of water is instantaneously injected into a well, and the subsequent recovery of the water level back to static (pre-injection level) is monitored.

Table 1. Results of Aquifer Testing Program.

Well Location	Test Date	Pumping Rate (gpm)	Coefficient of Transmissivity Drawdown gpm/ft ft^2/day	Recovery gpm/ft ft^2/day	Hydraulic Conductivity (ft/day)	Porosity	Storage Coefficient	Flow Rate (ft/yr)	Remarks
AQUIFER TESTS									
19.30.33.31	12-19,21-78	3.5		260/35	1.59	0.15		4.0	
20.30.15.31	12-28,29-78	14.7	3500/470	3500/470	26.11	.20		52.5	erratic pumping rate
20.30.23.11	12-29,30-78	3.8		87/12	1.2	.30		7.0	many small changes in discharge
20.32.17.13	12-19,22-78	10	2200/300	3640/350	6.63	.20		47.0	first 10 minutes of discharge were erratic, but became constant
20.32.22.33	12-19-78	10		40/5	.5	.30		4.3	
21.29.25.423a	01-11,12-79	4.5	160/20	145/20					variable discharge 15-3.3 gpm
21.29.25.423b	01-11,12-79			55/7			9.6×10^{-6}		observation well
21.31. 3.22	01-5,7-79	6.8	225/30	250/35	1.12	.30		9.3	
23.29.18.14	01-4,5-79	12		1380/185	6.6	.20		21.5	
20.33	01-18-79	17.6	1200/160	1000/135	12.29	.12		105	
28.41	12-15,18-78	11		300/40	5	.12		24.2	
	01-9,10-79	10			5				variable discharge, tape slipped, measurements not good
SLUG TESTS		Slug Volume (gal)	Transmissivity						
19.30. 5.32	03-14-79	10	14 ft^2/day		0.646	0.2	1×10^{-2}	6.0	
24.133	03-07-79	1st test: 6 gal. brine 2nd test: 6½ gal. fresh	251		25.1	.15	1×10^{-10}	232.0	very rapid recovery, water in aquifer is brine
35.23	03-14-79	10	9.4		1.045	.30	1×10^{-2}	17.7	
20.29.25.33	03-08-79	10	330		3.90	.15	1×10^{-14}	42.0	rapid recovery, possible brine aquifer
20.30.28.4	03-08-79	6.5	.06		.0032	.30	1×10^{-2}	.02	
29.33	03-13-79	10	3.0		.3775	.30	1×10^{-10}	2.1	
20.31. 2.34	03-12-79	10	.97		.060	.30	1×10^{-6}	.73	
27.24	03-08-79	10	.44		.04	.30	1×10^{-4}	.18	
23.29.26.12	03-06-79	10	.13		.02	.30	1×10^{-8}	.03	

Table 2. Characteristics of Test Wells.

Well Location	Depth of Well (feet)	Perforation (feet)	Test Date	Static Water Level (below top of casing) (feet)	Aquifer Thickness (feet)	Aquifer in Saturated Zone (%)	Lithology of Water-bearing Zone	Water Temperature (°F)	Altitude (ft) (top of casing)
AQUIFER TESTS									
19.30.33.31	50	30-50	12-19-78	20.66	22	75.8	silty shale	66.5	3,216.49
20.30.15.31	40	0-20	12-28-78	2.90	18	48.6	sand	66	3,198.95
20.30.23.11	100	80-100	12-29-78	72.99	10	40	silty calcareous shale	69	3,275.43
20.32.17.13	100	20-40	12-19-78	9.66	49	53.8	silty shale	65	3,450.35
20.32.22.33	170	150-169	12-19-78	29.77	10 perched	13.6	shale with anhydrite laminae	68.8	3,512.52
21.29.25.423 a	200+		01-11-79	67.57				66	
21.29.25.423 b			01-11-79						
21.31. 3.22	200	140-160	01-05-79	140.81 (03-15-79)	31	53.4	silty shale	65	3,519.59
23.29.18.14	35	15-35	01-04-79	7.10	28	100	sand & gravel	66	2,959.23
23.29.20.33	60	40-60	01-18-79	23.0	12	33	limestone	69	2,963.21
23.29.28.41	100	50-60 70-80	12-15-78	40.96	8	13.3	gypsum		2,988.16
	100	50-60 70-80	01-09-79	41.05	8			55	
SLUG TESTS									
19.30. 5.32	170	130-150	03-14-79	141.31	22	73.3	medium grained sand with some coarse fragments		3,345.19
19.30.24.133	70	50-70	03-07-79	52.13	10	55.5	brown silty shale		3,262.08
19.30.35.23	100	60-80	03-14-79	79.65	9	60	silty shale		3,265.59
20.29.25.33	180	140-160	03-08-79	87.27	84	90.32	gypsum		3,288.18
20.30.28. 4	220	200-220	03-08-79	171.24	19	39.5	anhydrite		3,373.05
20.30.29.33	150	130-150	03-13-79	134.63	8	50.0	silty shale with gypsum		3,333.30
20.31. 2.34	160	140-160	03-12-79	136.55	16	69.5	fine to medium grained sandstone with calcareous cement		3,482.89
20.31.27.24	150	130-150	03-08-79	114.43	11	23.9	siltstone stringers		3,530.23
23.29.26.12	160	140-160	03-06-79	107.75	6	11.5	anhydrite with thin bedded shale		3,030.88

In the tests run for this study, slug volumes of 6 to 10 gallons were used. Test times ranged from about an hour to several days, depending on how quickly the water level returned to static.

The method devised by Cooper, Bredehoeft, and Popadopulus (1967) and described in Lohman (1972, p. 28-29), was used to analyze the test results (appendix). Using this method, H/H_o is plotted on the arithmetic scale of semi-log paper where H is the head inside the well at time, t, after injection of slug above initial head, and H_o is the head inside the well above initial head at the moment of injection. Time is plotted on the logrithmic scale, in seconds.

Transmissivity values ranged from 0.06 to 330 ft^2 per day (table 1). Slug tests also give an estimate of storage coefficient values (Lohman, 1972, p. 29).

EVAPORATION AND LEAKAGE STUDY OF DISPOSAL PONDS

In August 1978 and January 1979 detailed field investigations were made of the hydrologic cycle of the waste-water systems of International Minerals Corporation (IMC) and Potash Company of America (PCA). The IMC site is located in Nash Draw and PCA is in Clayton Basin.

Several hydrologic studies have been performed in the area and are discussed in the 1978 Geohydrology Associates, Inc., report for the Bureau of Land Management, "Ground-water study related to proposed expansion of potash mining near Carlsbad, New Mexico." Earlier studies were general in nature and based on somewhat limited data. Therefore, a practical field approach was developed to quantify the hydrologic-system parameters, including: amount of inflow into ponds; rate of evaporation; pond-level changes; pond leakage.

Field work was performed during two three-day periods. The first study was made in August 1978 when daytime temperatures exceeded 100° F and there was no precipitation. The second study was made in January 1979 in order to measure the hydrologic parameters during cool and moist climatic conditions.

Site Descriptions and Previous Work

International Minerals & Chemical Corporation. Discharge from IMC flows from the refinery to its spoil pile and to Laguna Uno. Laguna Uno is a natural brine lake, one of several that is located north of Salt Lake. The surface of Laguna Uno represents the level of the local water table;

and numerous springs discharge into the lake along its northeast side. Aerial photos taken in 1975 indicated the lake size was 562 acres. In August 1978, project staff members plane-table mapped the lake and found its size to be 710 acres.

In 1977, IMC imported 1,894,622,800 gallons of water from the Ogallala aquifer for use in its refinery process (Geohydrology Associates, Inc., 1978, p. 73). It is estimated that 90 percent of this water is discharged as waste. This represents an average continuous discharge of 3,244 gpm.

Laguna Uno has no surface outflow channel. All water discharged into the lake by natural springs or as refinery discharge either evaporates or enters the ground-water system by pond leakage. Geohydrology Associate's 1978 water budget indicated an average leakage rate of 822 gpm. Average evaporation rate was calculated at 641 gpm. Ground-water movement at Laguna Uno is southward toward Salt Lake.

Potash Company of America. The PCA disposal pond is a man-made lake created by the ponding of refinery waste water in what was once a broad open depression. The size of the pond fluctuates with the water level, but average surface area throughout the year is about 450 acres (Geohydrology Associates, Inc., 1978, p. 80). There is no surface-water outlet.

Refinery discharge into the pond was at a rate of 2,550 gpm (Mr. Dave Rice, Vice President, Ideal Basic Industries, Potash Company of America Division, written commun., Feb. 8, 1978). Geohydrology Associates, Inc., (1978, p. 81) calculated a leakage of about 1,100 gpm through the pond bottom. Once into the ground-water system, the water follows the local ground-water gradient toward Clayton Lake.

The presence of natural brine ponds south and east of the PCA pond indicates that it is located in an area of ground-water discharge. The amount of ground-water inflow into the PCA pond is unknown.

Field Study

In an effort to further define the water-budget parameters at IMC and PCA, a field investigation was undertaken by Geohydrology Associates. Field work was performed during a four-day period in August 1978 and again during a three-day period in January 1979. The study was performed in both summer and winter to determine the effects of season on rates of evaporation amount of loss from the spoil piles, and lake-level changes.

By isolating the parameters of pond inflow and pond evaporation, and observing the net water-level change of the disposal ponds through a period of time, a leakage rate value could be determined. This is shown diagrammatically in figure 5.

Measurement of Inflow to Ponds. The IMC refinery waste water is discharged onto a spoil pile. The spoil pile is 619 acres in size and consists primarily of salt (Geohydrology Associates, Inc., 1978, p. 71). The spoil-pile surface is sloped toward Laguna Uno. Water moves across the surface of the pile as well as through its interior toward Laguna Uno. Below the spoil pile, the waste water crosses a large salt flat and discharges across an extensive delta of deposited refinery-waste solids into the north end of Laguna Uno. The flow-path from refinery discharge point to the lake is about a half to three-quarters of a mile.

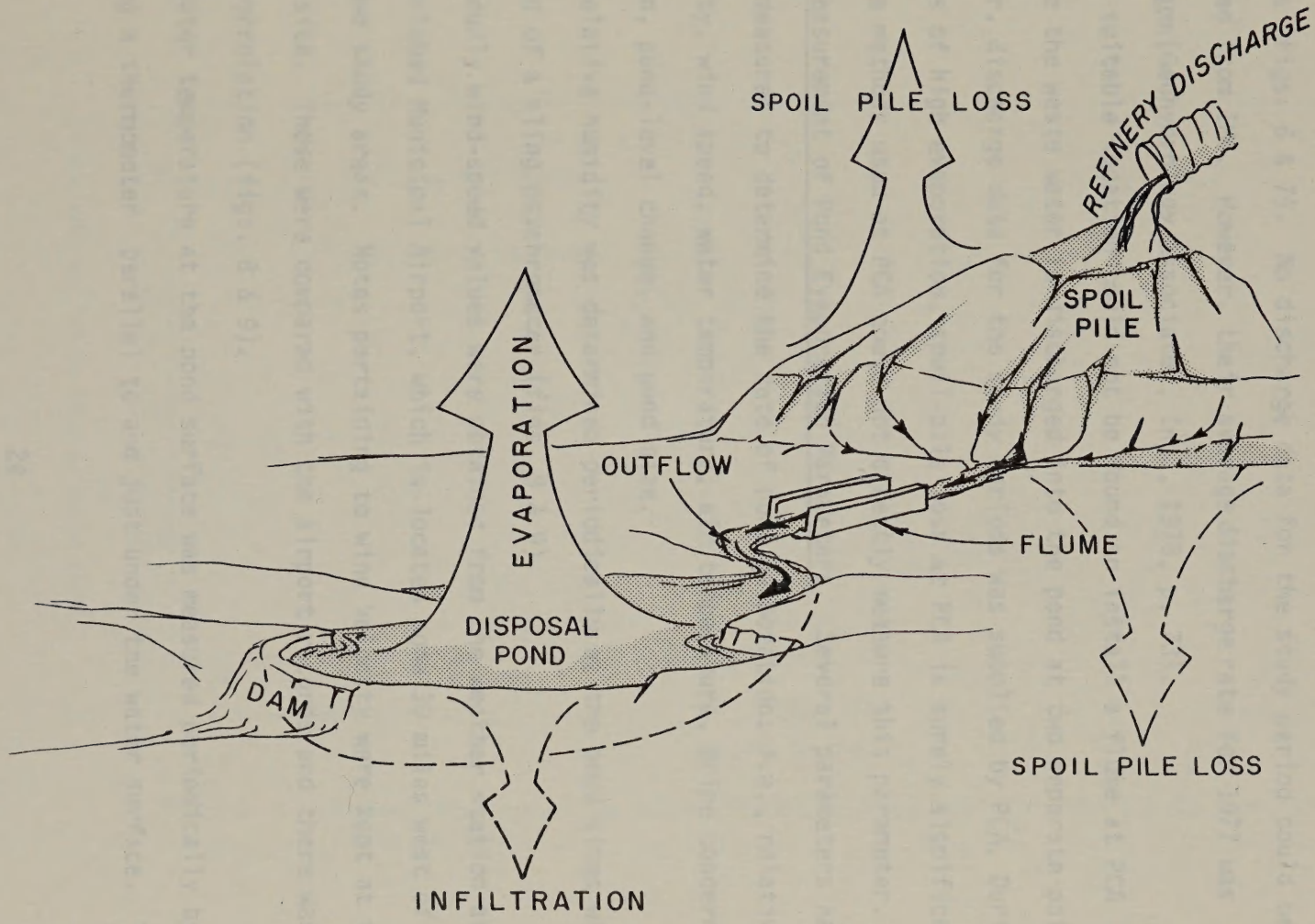


Figure 5. Dispersal of refinery discharge, shown diagrammatically.

A Parshall Flume was used to measure the amount of discharge into Laguna Uno. It was installed on the salt flats below the spoil pile and above the point of discharge into the lake. Frequent measurements were taken, and detailed discharge record was obtained for the period of the studies (figs. 6 & 7). No discharge data for the study period could be obtained from IMC. However, their average discharge rate for 1977 was 3,244 gpm (Geohydrology Associates, Inc., 1978, p. 73).

A suitable location could not be found to install a flume at PCA because the waste water is discharged into the pond at two separate points. However, discharge data for the study periods was supplied by PCA. During periods of high evaporation, spoil-pile loss at PCA is surely significant, but the methods used at PCA could not directly measure this parameter.

Measurement of Pond Evaporation Parameters. Several parameters had to be measured to determine the rate of pond evaporation; i.e., relative humidity, wind speed, water temperature, air temperature, brine concentration, pond-level change, and pond size.

Relative humidity was determined periodically at the pond sites with the aid of a sling psychrometer (figs. 8 & 9).

Hourly wind-speed values were obtained from the weather station at the Carlsbad Municipal Airport, which is located some 30 miles west of the pond study areas. Notes pertaining to wind velocity were kept at the study site. These were compared with the airport records and there was good correlation (figs. 8 & 9).

Water temperature at the pond surface was measured periodically by holding a thermometer parallel to and just under the water surface. The

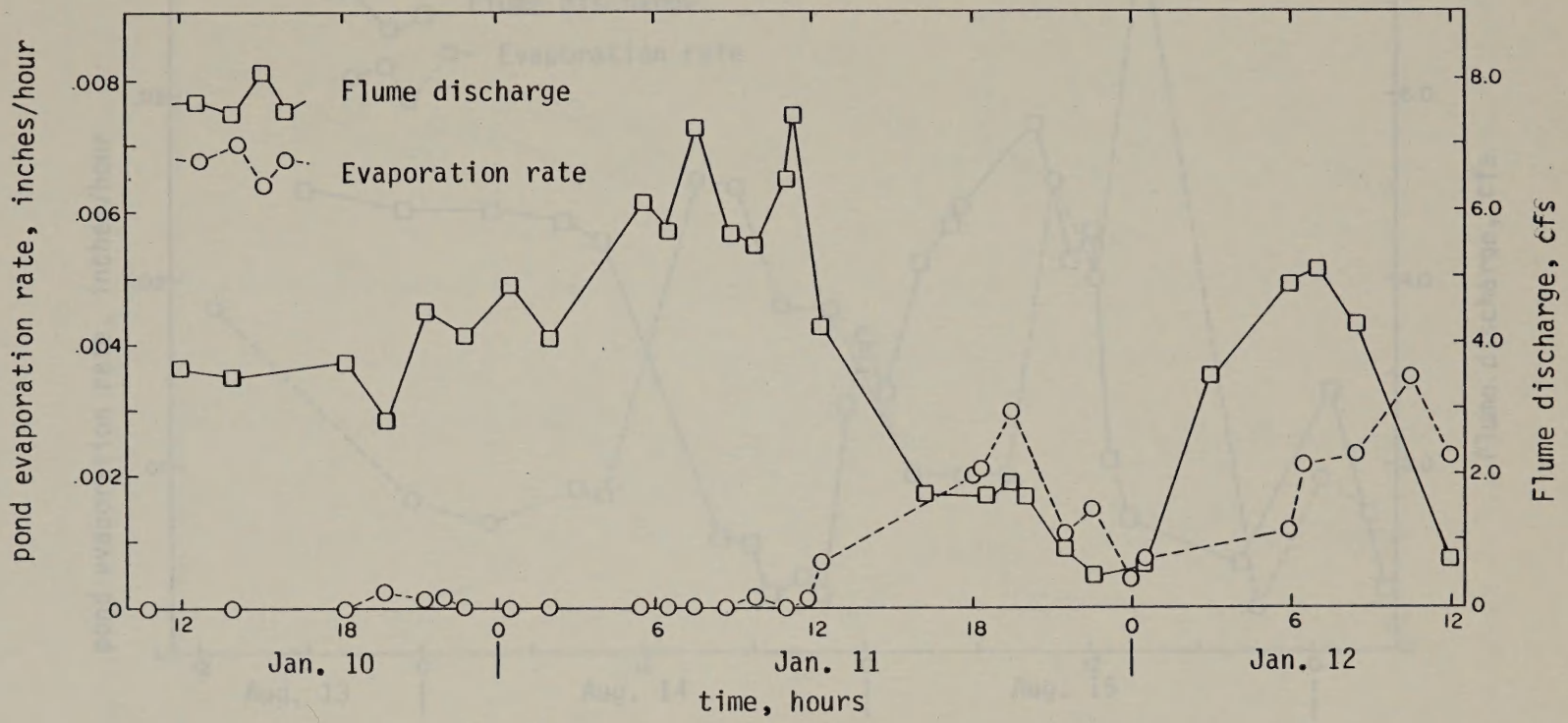
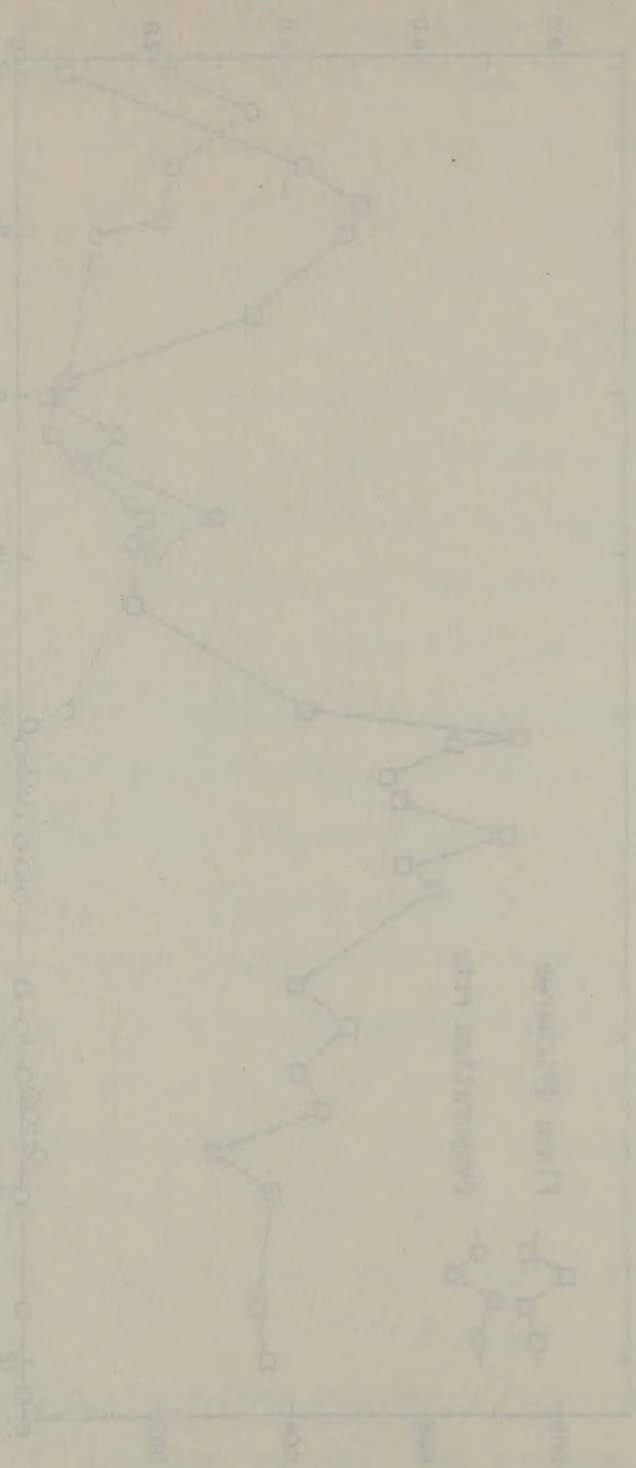


Figure 6. Evaporation rate and flume-discharge rate for the IMC, Laguna Uno, winter study period.



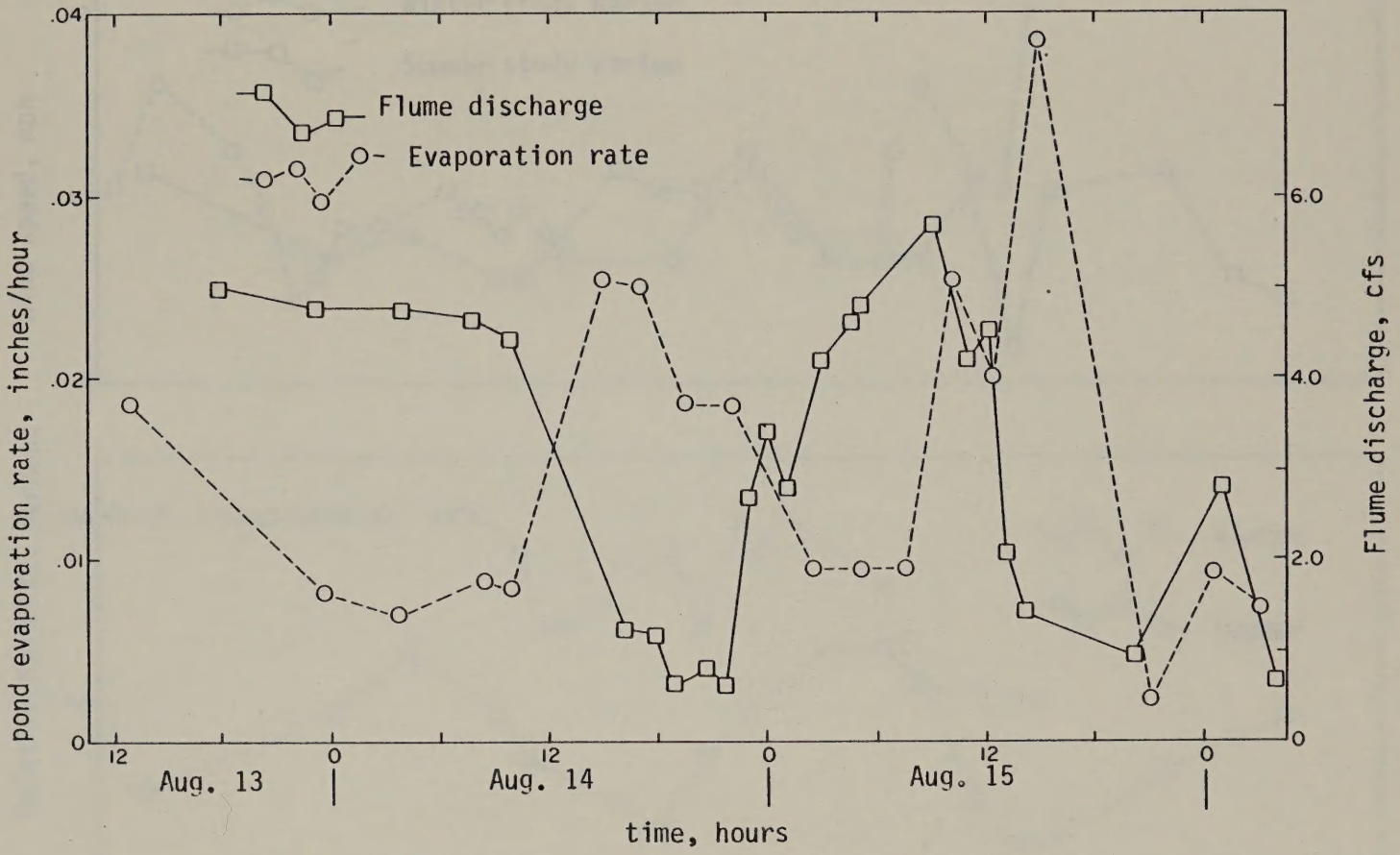
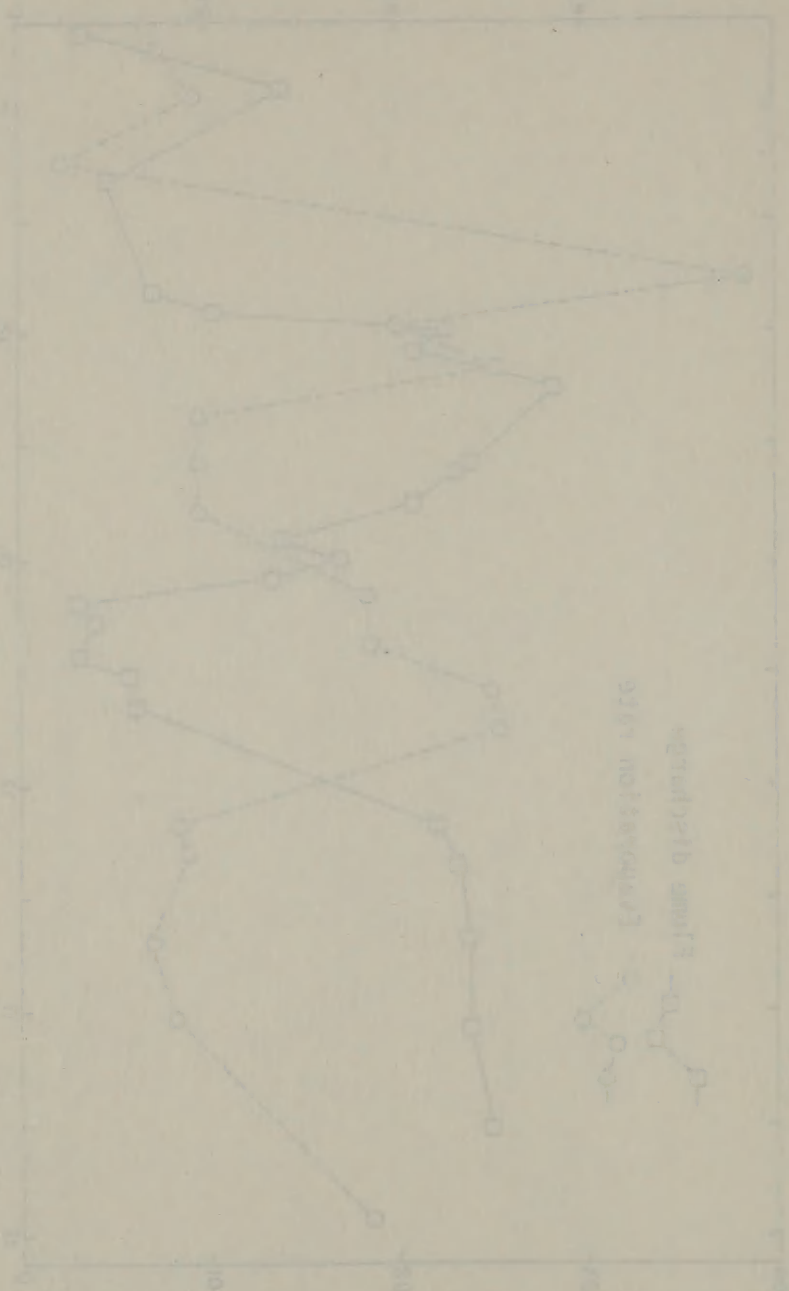


Figure 7. Evaporation rate and flume discharge rate for the IMC disposal pond, Laguna Uno, for the summer period.



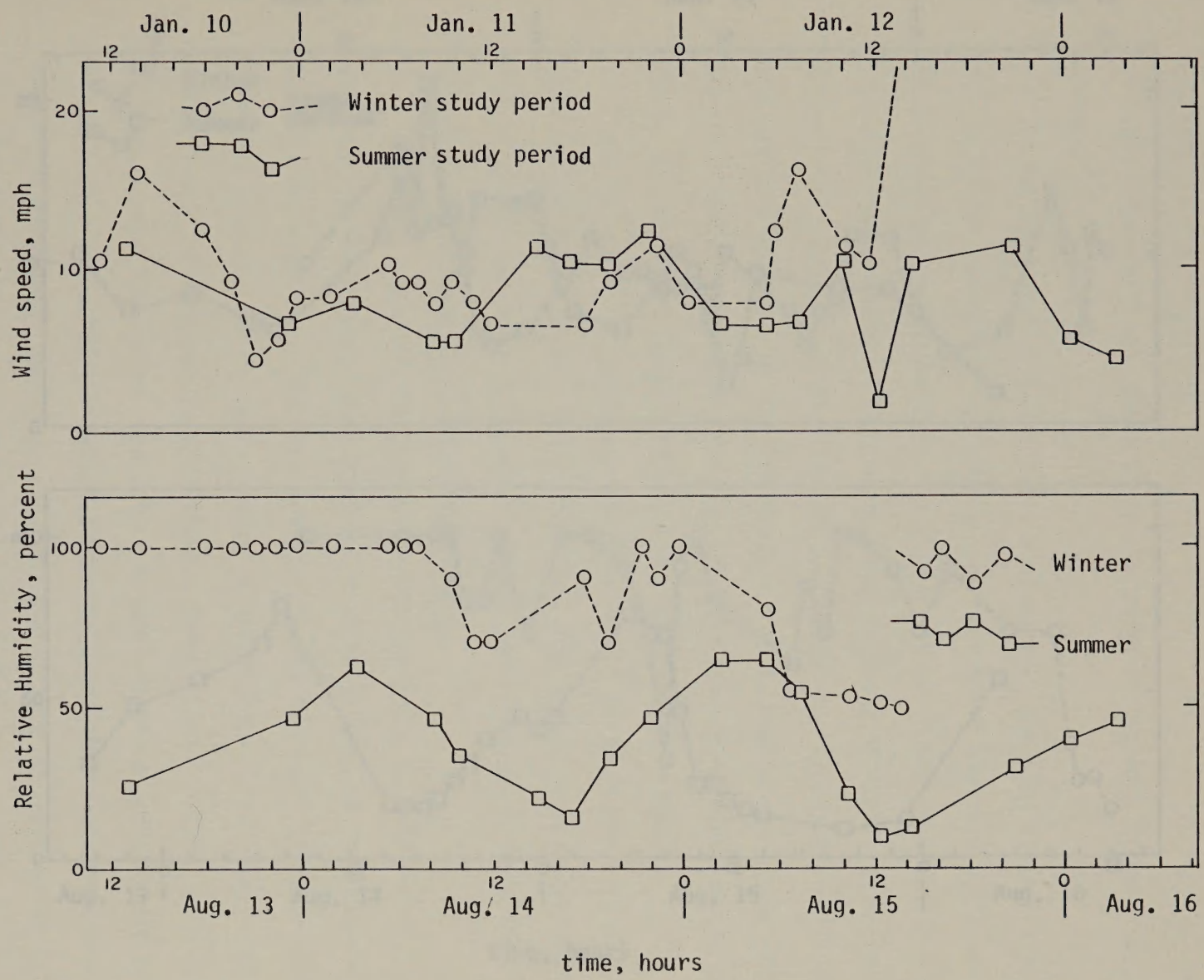
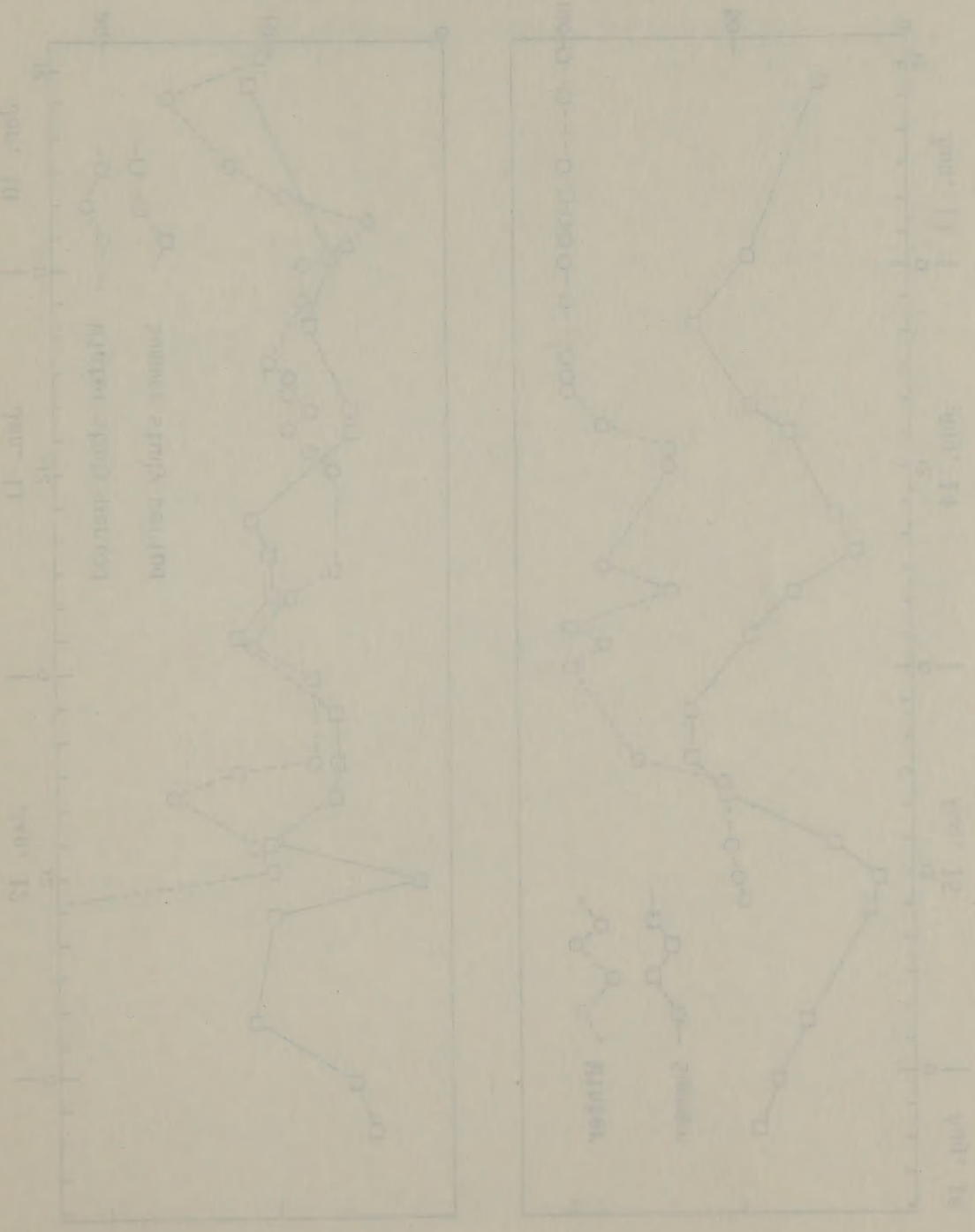


Figure 8. Wind speed at the Carlsbad Airport and relative humidity at the IMC disposal pond, Laguna Uno, for the summer and winter study periods. Each date shown applies to both graphs.



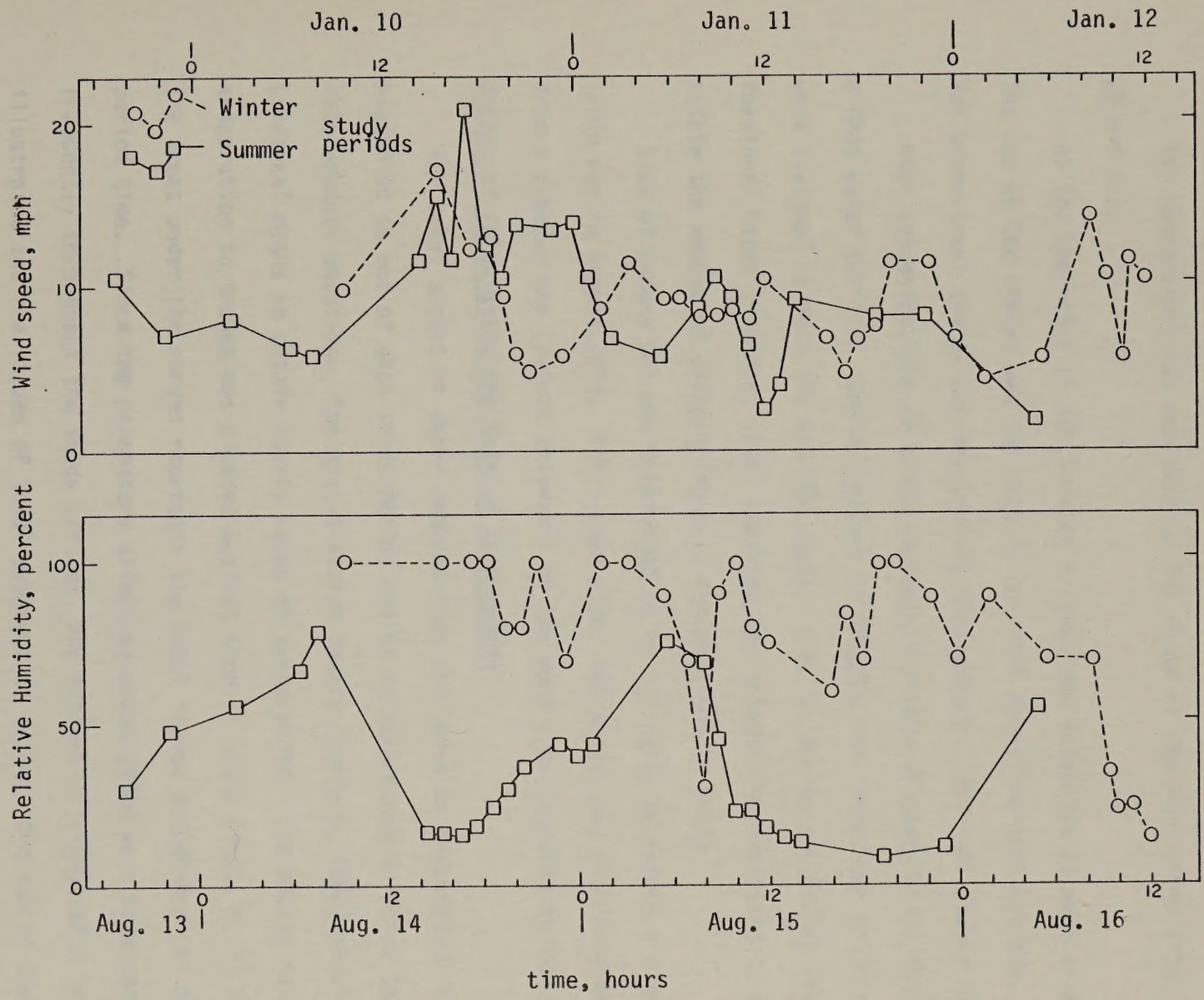


Figure 9. Wind speed at the Carlsbad Airport and relative humidity at the PCA pond disposal for the summer and winter study periods.

Each date shown applies to both graphs.

measurements were taken from shore where water was generally less than a foot deep (figs. 10 and 11).

Air temperature was measured in the shade at the pond sites (figs. 10 and 11).

At the beginning of the studies a stake was installed at each site. The top of the stakes was set exactly one foot above the pond surface. Net water-level change was measured to the nearest 0.005 foot (table 3).

High concentrations of brine decrease the rate of evaporation from a free water surface. Concentrations of 300,000 ppm (parts per million) were assigned to both IMC and PCA ponds. A U. S. Geological Survey Professional Paper (Harbeck, 1955) supplied the information necessary to calculate the amount of evaporation rate decrease due to brine.

Size of Laguna Uno was determined to be 710 acres by making a plane-table map in August 1978. PCA's pond size, 450 acres, was planimetered from a contour map (2-foot interval) of the pond area supplied by PCA.

Method of Calculating the Rate of Evaporation

The total amount of water removed from the ponds by evaporation from beginning to end of each study period had to be determined to solve the water-budget equation. The mass-transfer theory (Harbeck, 1962) provided a practical means to obtain hourly rates of evaporation. The hourly rate of evaporation in inches was plotted against time in hours (figs. 6, 7, 12, 13). The areas under the curves represent the total inches evaporated per total study-period time. Since the parameters affecting evaporation were measured frequently throughout the study periods, the pattern of evaporation is well illustrated and the values of total evaporation reflect the sum of the effect of changes in temperature, wind speed, and humidity.

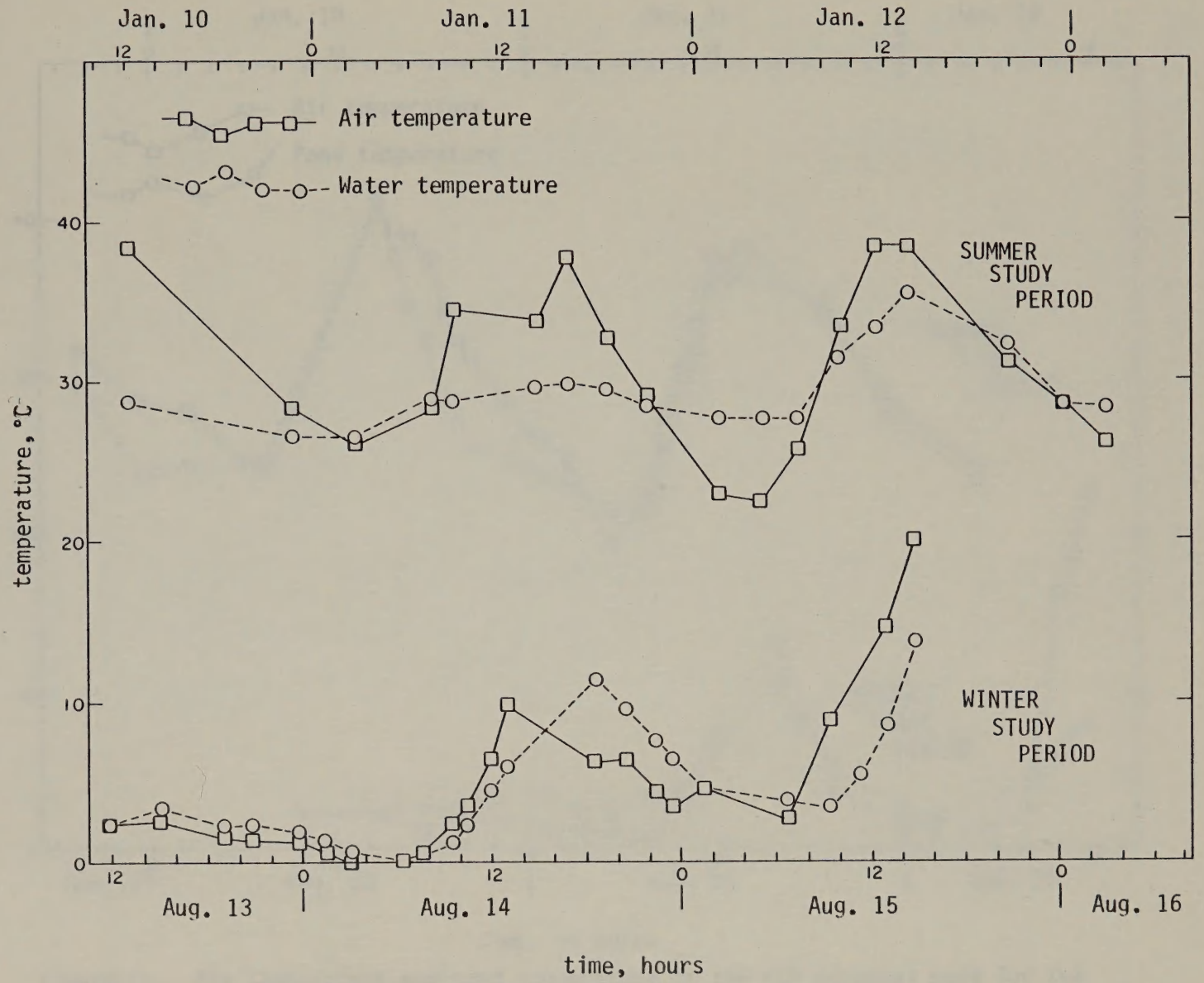
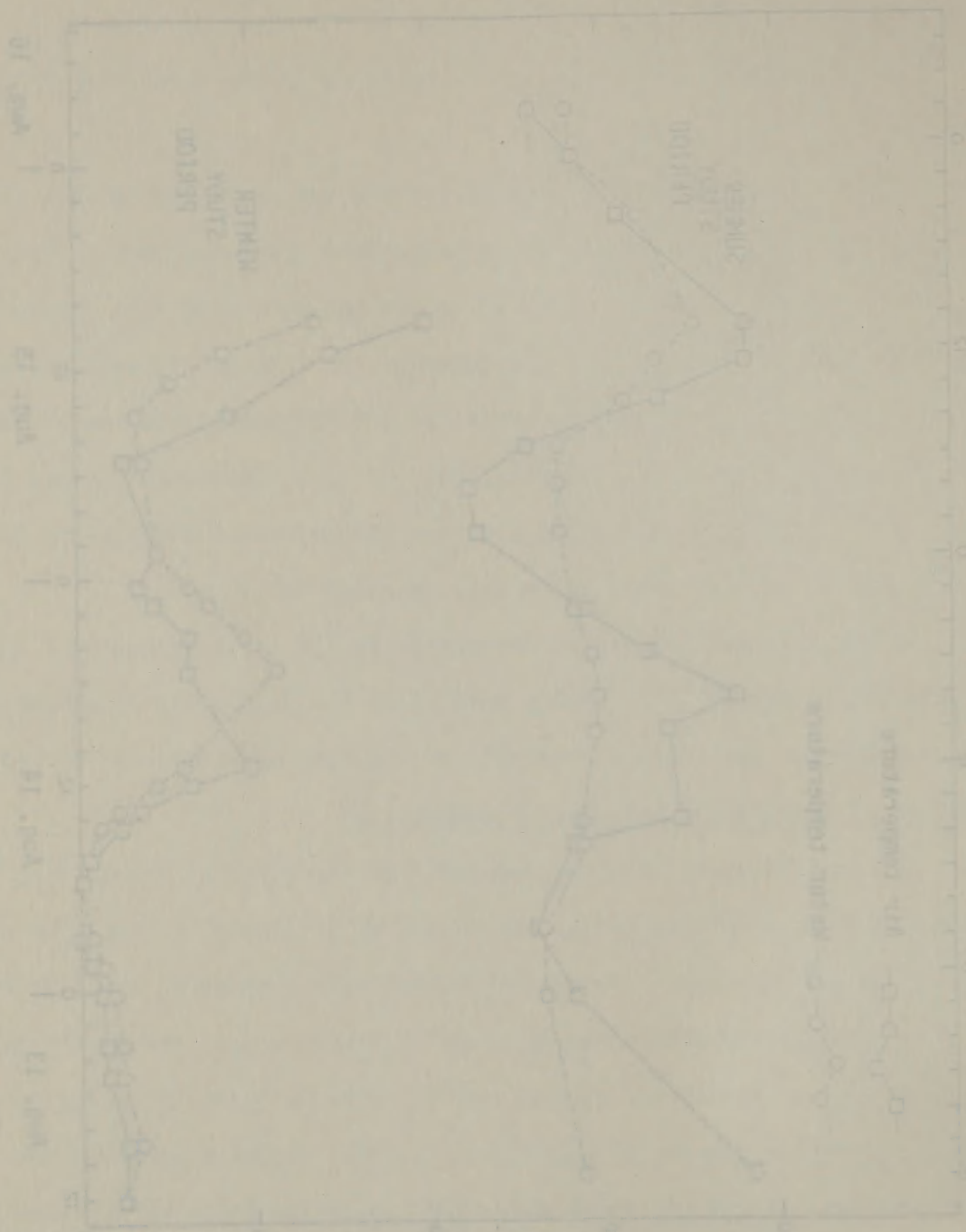


Figure 10. Air Temperature and pond temperature at the IMC disposal pond, Laguna Uno, for the summer and winter study periods.



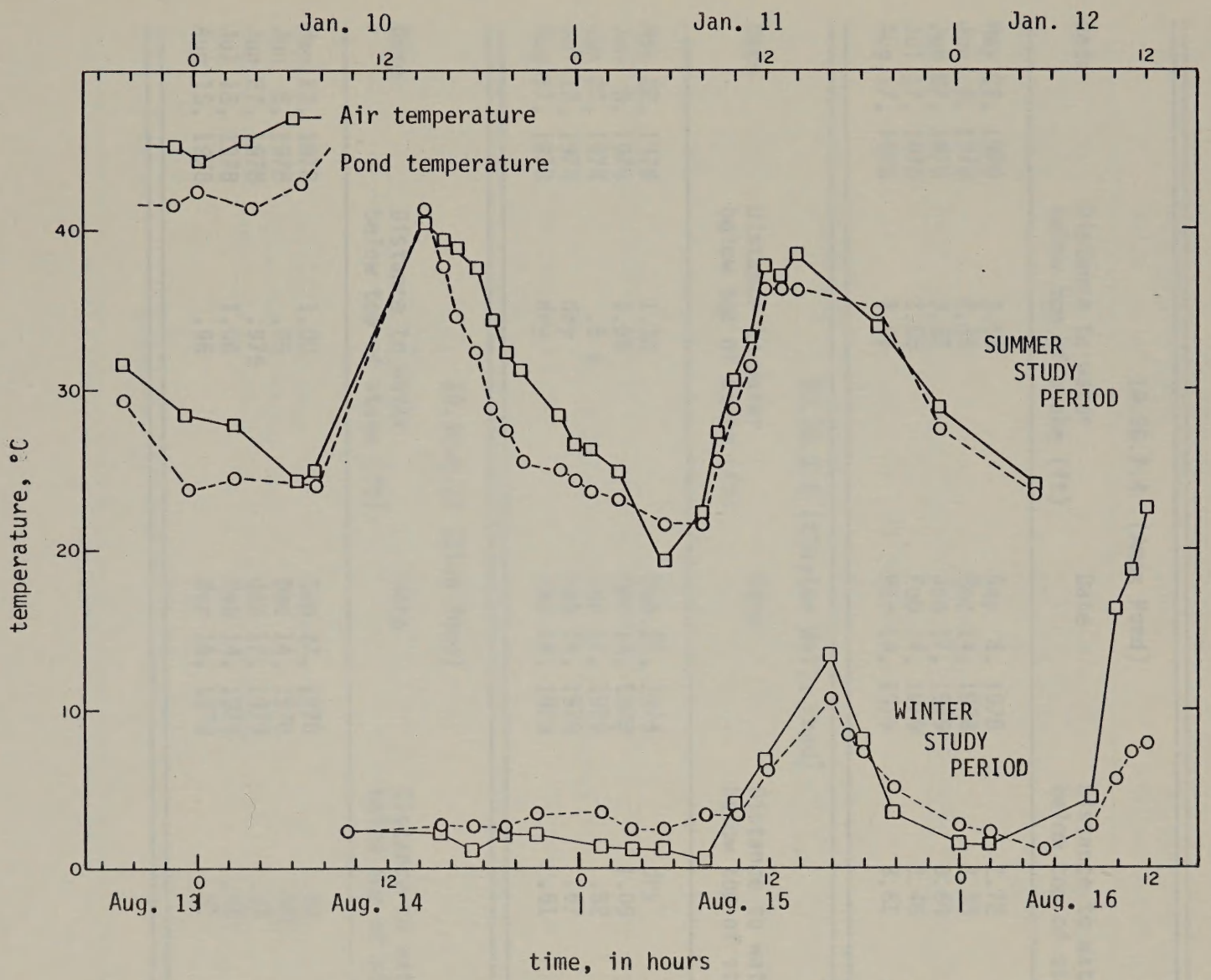


Figure 11. Air temperature and pond temperature at the PCA disposal pond for the summer and winter study period.

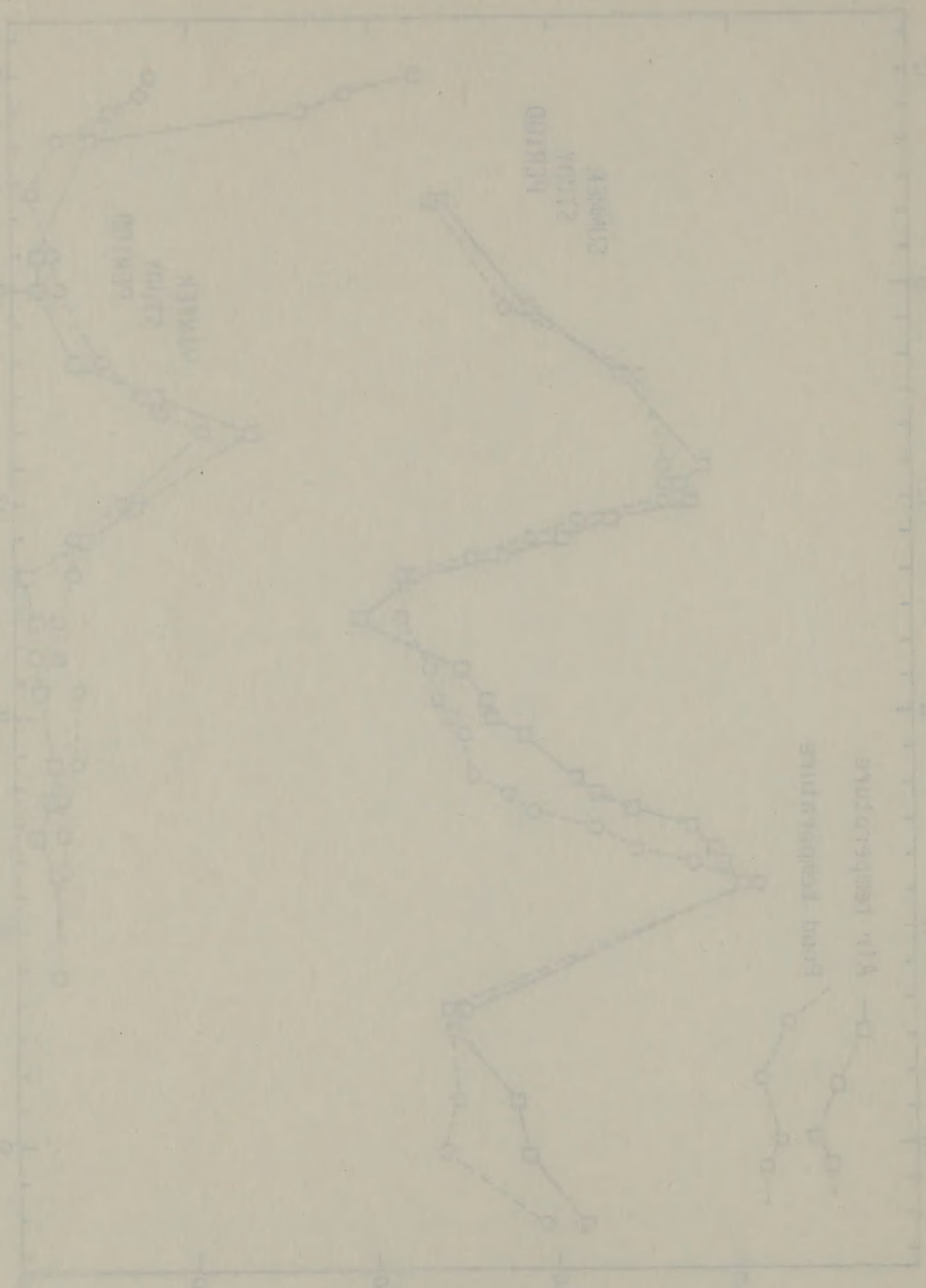


Table 3. Water-level records for selected ponds.

19.30.7.4 (Amax Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 22, 1978	3.13	Sep 8, 1978	2.72
Jun 8, 1978	2.36	Dec 14, 1978	3.33
Jun 27, 1978	3.52	Jan 17, 1979	3.64
Jul 17, 1978	3.65	Feb 14, 1979	3.46
Aug 17, 1978	3.55	Mar 14, 1979	3.61

20.30.3.2 (Clayton Wells Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 22, 1978	1.38	Sep 27, 1978	dry
Jun 8, 1978	1.55	Dec 14, 1978	1.09
Jun 27, 1978	.5 ±	Jan 17, 1979	.82
Jul 17, 1978	dry	Feb 14, 1979	.67
Aug 17, 1978	dry	Mar 14, 1979	.61

20.30.8.32 (Blue Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.00	Sep 27, 1978	.93
Jun 8, 1978	.99	Dec 14, 1978	.885
Jun 27, 1978	.975	Jan 17, 1979	.57
Jul 18, 1978	1.06	Feb 14, 1979	.48
Aug 15, 1978	.96	Mar 15, 1979	.51

Table 3. Water-level records for selected ponds, continued.

20.30.8.323 (Green Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.06	Sep 27, 1978	1.02
Jun 8, 1978	1.06	Dec 14, 1978	1.02
Jun 27, 1978	1.07	Jan 17, 1979	1.03
Jul 18, 1978	1.16	Feb 14, 1979	1.00
Aug 15, 1978	1.02	Mar 15, 1979	.98

20.30.8.34 (Stock Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.27	Sep 27, 1978	submerged
Jun 8, 1978	.060	Dec 14, 1978	.67
Jun 27, 1978	dry	Jan 17, 1979	.54
Jul 18, 1978	1.55	Feb 14, 1979	.545
Aug 15, 1978	dry	Mar 15, 1979	.70

20.30.8.center (PCA, nail at trestle)

Date	Distance to water below top of nail (ft)	Date	Distance to water below top of nail (ft)
Aug 15, 1978	2.41	Jan 17, 1979	submerged .35
Sep 27, 1978	.86	Feb 13, 1979	submerged .575
Dec 13, 1978	submerged .14	Mar 15, 1979	submerged .545

20.30.15.3

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 22, 1978	1.34	Jan 17, 1979	submerged .30
Jun 8, 1978	1.22	Feb 13, 1979	submerged .46
Sep 27, 1978	1.39	Mar 15, 1979	submerged .45
Dec 13, 1978	submerged .04		

Table 3. Water-level records for selected ponds, continued.

20.30.16.2 (Culvert Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 22, 1978	1.38	Sep 27, 1978	.71
Jun 8, 1978	.97	Dec 14, 1978	.73
Jun 27, 1978	dry	Jan 17, 1979	.69
Jul 17, 1978	dry	Feb 14, 1979	.68
Aug 17, 1978	dry	Mar 15, 1979	.75

20.30.34.1 (Duval Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	3.54	new stake:	
Jun 8, 1978	3.36	Feb 13, 1979	.21 at installation
		Mar 15, 1979	.34

20.31.13.4 (Williams Sink)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.25	Dec 13, 1978	submerged 2.5 ±
Jun 8, 1978	.41	Jan 17, 1979	submerged 2.5 ±
Jun 27, 1978	.768	Feb 13, 1979	submerged
Aug 17, 1978	1.30	Mar 15, 1979	submerged 1. ±
Sep 27, 1978	submerged .09		

21.29.12.3 (MCC Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.17	Dec 13, 1978	2.896
Jun 7, 1978	1.52	Jan 17, 1979	2.983
Jul 18, 1978	.75	Feb 13, 1979	2.688
Aug 17, 1978	1.75	Mar 15, 1979	3.42
Sep 27, 1978	2.83		

Table 3. Water-level records for selected ponds, continued.

22.29.26.1 (Lindsey Lake)

Date	Distance to water below top of pole (ft)	Date	Distance to water below top of pole (ft)
May 23, 1978	2.79	Sep 19, 1978	2.72
Jun 7, 1978	2.75	Dec 13, 1978	2.74
Jun 27, 1978	2.74	Jan 17, 1979	2.72
Jul 19, 1978	2.80	Feb 13, 1979	2.74
Aug 17, 1978	2.73	Mar 15, 1979	2.72

22.30.19.3 (Inlet Laguna Uno)

Date	Distance to water below top of stake (ft)
Feb 13, 1979	.92
Mar 15, 1979	.975

22.30.19.33 (IMC Stake)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	.83	Sep 19, 1978	.89
Jun 7, 1978	.92	Dec 13, 1978	.87
Jun 27, 1978	.872	Jan 16, 1979	.87
Jul 19, 1978	1.0	Feb 13, 1979	.87
Aug 16, 1978	1.08	Mar 15, 1979	.885

22.30.19.34 (Offset Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.42	Jul 19, 1978	1.38
Jun 7, 1978	1.05	Aug 16, 1978	1.33
Jun 27, 1978	1.07	Sep 19, 1978	1.07

22.30.30 (IMC J Bar F Stake)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
Aug 16, 1978	.92	new stake:	
Sep 19, 1978	1.07	Dec 13, 1978	1.0 at installation
		Jan 12, 1979	.89
		Feb 13, 1979	.82

Table 3. Water-level records for selected ponds, concluded.

22.30.31.4 (N. Nash Well Pond)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	.94	Sep 19, 1978	dry (?)
Jun 7, 1978	.89	Dec 13, 1978	.93
Jun 27, 1978	1.02	Jan 16, 1979	.90
Jul 18, 1978	1.20	Feb 13, 1979	.875
Aug 16, 1978	1.14	Mar 15, 1979	.95

23.29.3.1 (Salt Lake Tributary)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	1.52	Sep 19, 1978	dry
Jun 7, 1978	1.44	Dec 13, 1978	1.31
Jun 27, 1978	1.57	Jan 16, 1979	1.33
Jul 18, 1978	1.67	Feb 13, 1979	1.33
Aug 16, 1978	1.56	Mar 15, 1979	1.37

23.29.3.2 (Mile Marker 2)

Date	Distance to water below top of post (ft)	Date	Distance to water below top of post (ft)
May 23, 1978	3.65	Sep 19, 1978	dry
Jun 7, 1978	3.57	Dec 13, 1978	3.87
Jun 27, 1978	dry	Jan 16, 1979	3.91
Jul 18, 1978	dry	Feb 13, 1979	3.90
Aug 16, 1978	dry	Mar 15, 1979	dry

23.29.4.3 (Salt Lake)

Date	Distance to water below top of stake (ft)	Date	Distance to water below top of stake (ft)
May 23, 1978	submerged .15	Sep 19, 1978	.06
Jun 7, 1978	.15	new stake:	
Jun 27, 1978	.12	Jan 16, 1979	.1 at installation
Jul 18, 1978	.26	Feb 13, 1979	.09
Aug 16, 1978	0.0	Mar 15, 1979	.235

(Hackberry Lake)

Date	Distance to water below top of stake (ft)
Dec 13, 1978	.3 ±
Jan 17, 1979	.72

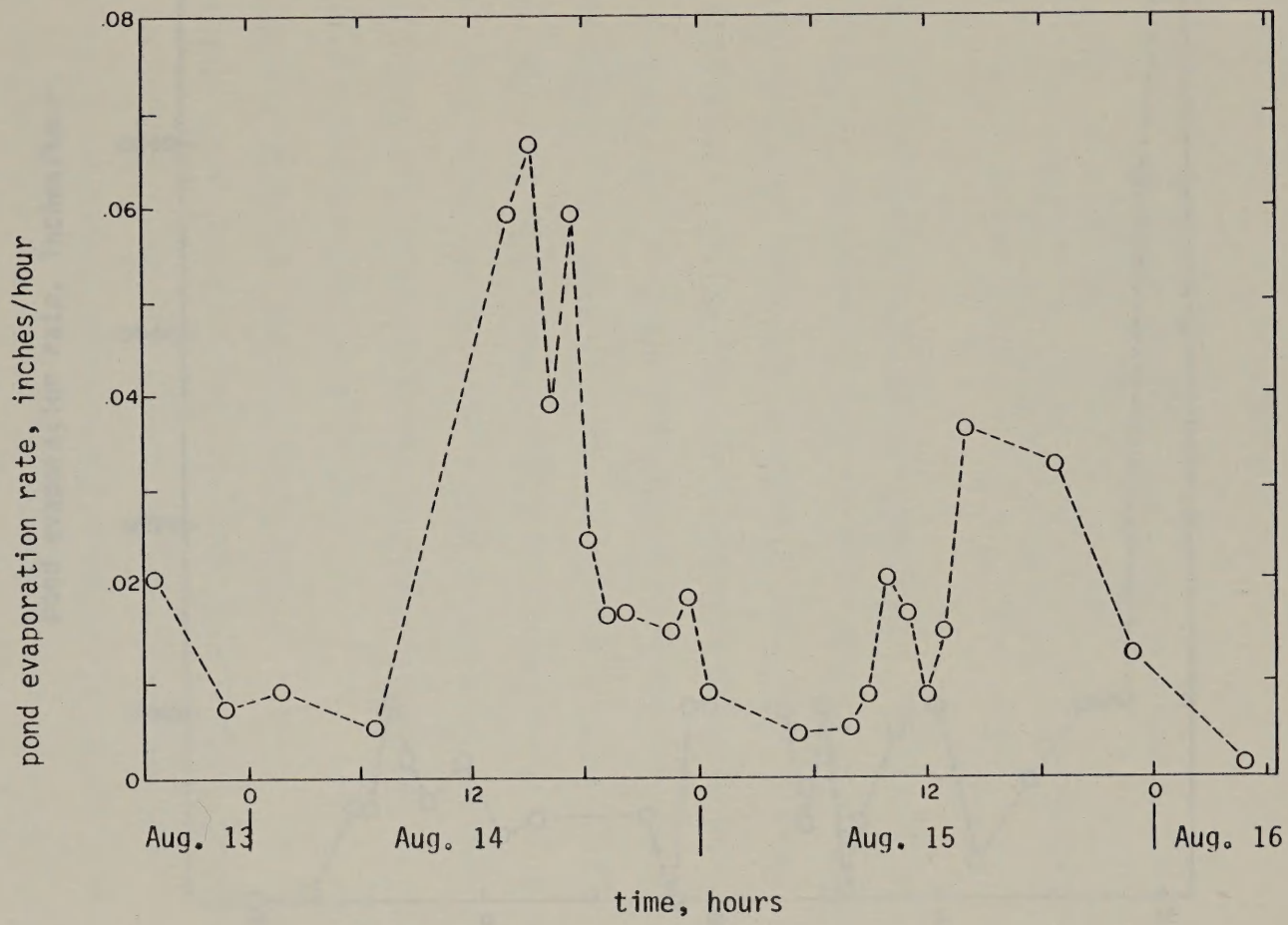
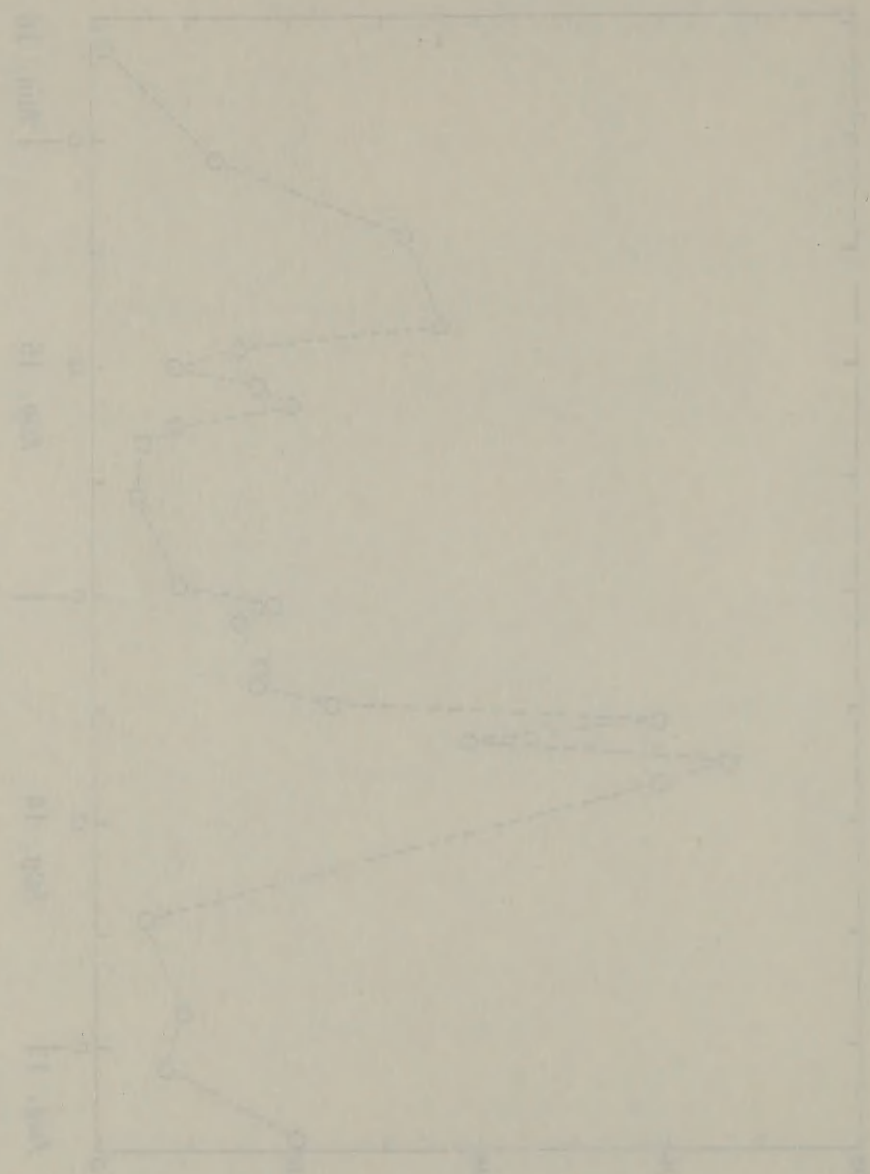


Figure 12. Pond evaporation rate for the PCA disposal pond for the summer study period.



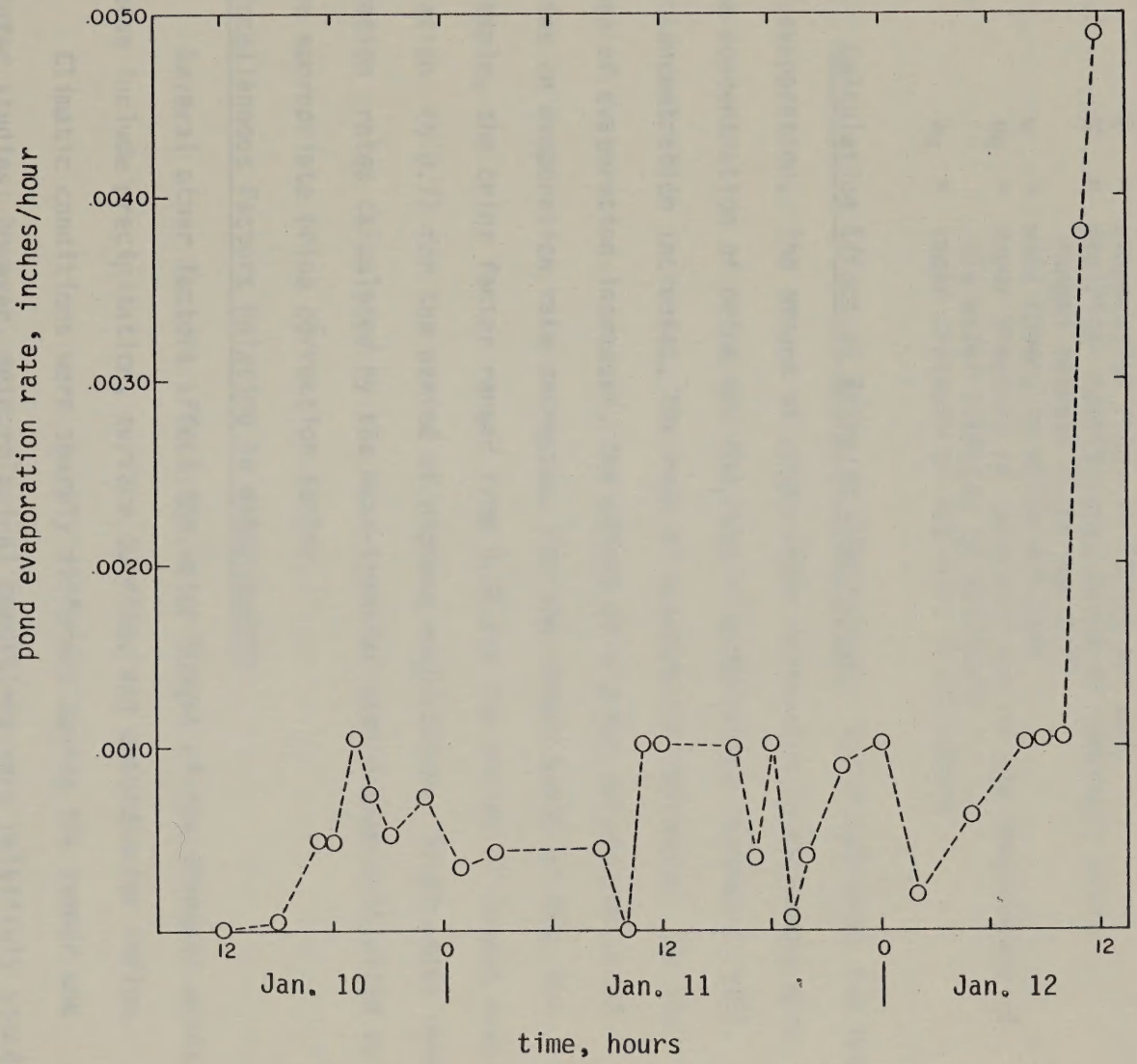
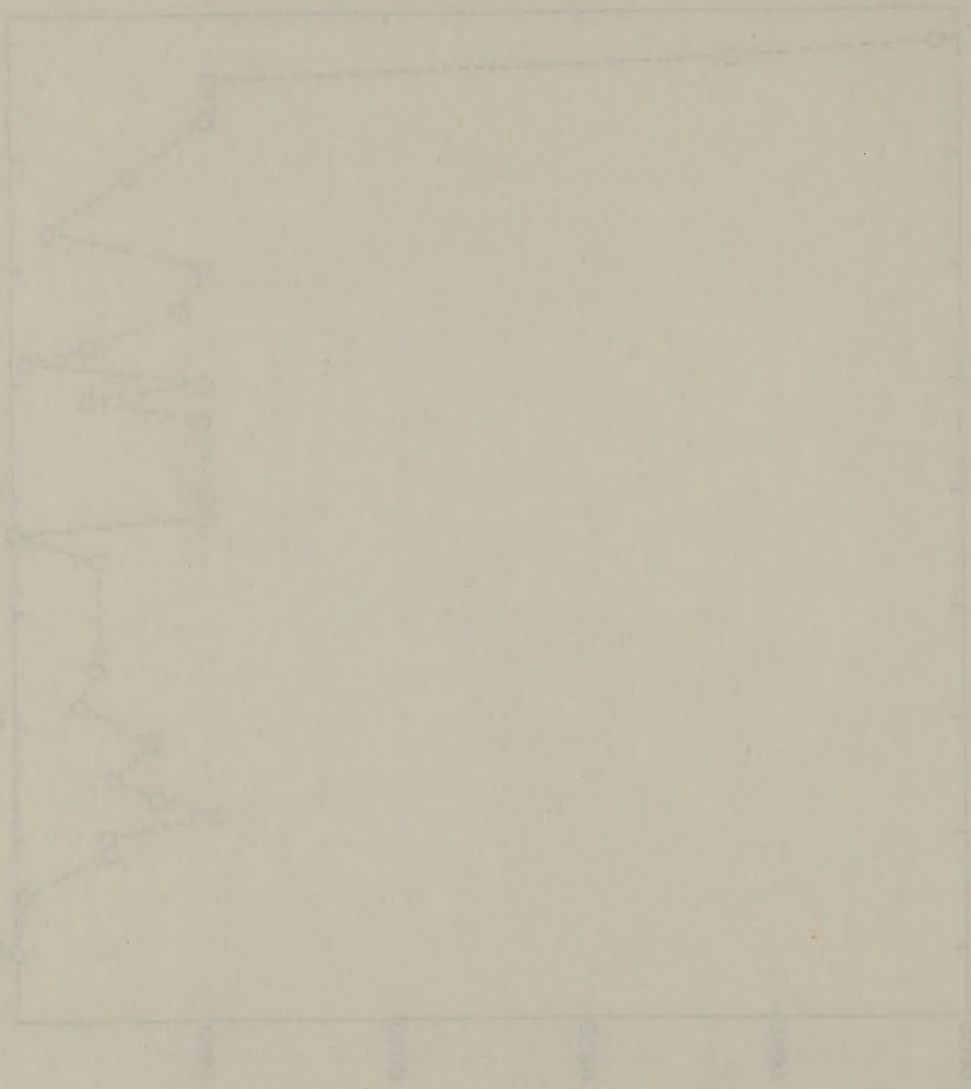


Figure 13. Pond evaporation rate at the PCA disposal pond for the winter study period.



The mass-transfer theory uses a quasi-empirical equation to calculate evaporation in inches per day. It is:

$$E = Nu\ (e_o - e_a)$$

E = evaporation rate, in inches per day
N = empirical coefficient, based on reservoir size; ranges between 0.001 and 0.01
u = wind speed, in miles per hour
e_o = vapor pressure of saturated air at the temperature of the water surface, in millibars
e_a = vapor pressure of the air, in millibars

Calculating Effect of Brine on Evaporation. Brine decreases the rate of evaporation. The amount of evaporation depression is dependent upon the concentration of brine and the rate of evaporation (Harbeck, 1955). As concentration increases, the rate of evaporation decreases. As the rate of evaporation increases, the effect of a given concentration of brine on evaporation rate decreases. For the summer study of PCA, for example, the brine factor ranged from 0.64 for the period of lowest evaporation to 0.77 for the period of highest evaporation. Fresh water evaporation rates calculated by the mass-transfer method were multiplied by the appropriate brine correction factor.

Miscellaneous Factors Relating to Water Budget

Several other factors affect the water budget of the disposal ponds. These include precipitation, surface outflow, and ground-water inflow.

Climatic conditions were sharply different during the summer and winter studies; however, meteorological conditions were relatively steady for the duration of the field work during each study period. No precipitation was recorded during the evaporation study, so precipitation

is zero in the water budget determinations.

Neither Laguna Uno nor the PCA pond has any surface outflow; this factor was also zero in the water-budget equation. There is a string of lakes entending from Laguna Uno to Salt Lake, and there is little doubt that these lakes are hydrologically connected. Therefore, it can be assumed that water from Laguna Uno does enter a surface water system, but the initial outflow from that lake is by ground-water flow.

Laguna Uno receives a significant amount of water from springs. The northeast side of the lake is bounded by a series of springs that discharge saline water. The discharge probably varies seasonally; however, there was no way to measure the total discharge because many of these areas are simply small seeps. Estimates based on field observation indicate a total spring contribution of at least 400 gpm. A ground-water inflow of 500 gpm was used in the water-budget equation for both the summer and winter studies.

The PCA disposal pond is located in an area of ground-water discharge. Several springs are located along the south side of the lake, and there are several seeps and springs located southeast of the pond. These could not be directly measured and are assumed to be relatively minor contributors of ground water to the pond, therefore the total was assumed to be zero.

Water-Budget Equation

For a given length of time, the water budget for a given pond is expressed by the general equation:

$$I_t - O_t - E_t - \Delta H = \emptyset$$

or

$$\Delta H = I_t - O_t - E_t$$

where,

I_t = total amount of water flowing into the pond, which includes:

- i_g = ground-water inflow
- i_s = surface-water inflow, including refinery discharge
- i_p = direct inflow of water from local precipitation

O_t = total amount of water flowing out of the pond, which inclues:

- O_s = surface-water loss (streams)
- O_1 = leakage through the pond bottom

E_t = total loss of water from the pond by evaporation

ΔH = observed net pond level change

During this study no precipitation was recorded, therefore $i_p = \emptyset$. Neither Laguna Uno nor the PCA pond has any surface-water outflow, therefore $O_s = \emptyset$. The resulting equation,

$$(i_g + i_s + i_p) - (O_s + O_g) - E_t - \Delta H = \emptyset$$

or

$$O_g = i_g + i_s - E_t - \Delta H$$

is valid to find the leakage of ground water from Laguna Uno. Calculation units are inches of lake-level change. For example, a surface-water inflow of 1,000 gpm for a 49-hour period would raise the water level of Laguna Uno 0.15 inches.

It should be emphasized that the leakages calculated below are applicable only for the periods of study. The rates are believed to represent maximum and minimum possible values due to meteorological conditions which existed during the study periods.

IMC: $O_g = i_g + i_s - E_t - \Delta H$

summer (56-hour): $i_g = 0.09$ in., $i_s = 0.37$ in., $E_t = 0.83$ in., $\Delta H = -0.39$ in.

$O_g = 0.09 + 0.37 - 0.83 - (0.39)$

$O_g = 0.02$ in. $\simeq$ 110 gpm

winter (49-hour): $i_g = 0.08$ in., $i_s = 0.56$ in., $E_t = 0.04$ in., $\Delta H = 0.09$ in.

$O_g = 0.08 + 0.56 - 0.04 - 0.09$

$O_g = 0.51$ in. $\simeq$ 3,330 gpm

PCA: For PCA, i_g, i_p, and O_s all equal zero. Therefore,

$O_g = i_s - E_t - \Delta H$

summer (57.3-hour): $i_s = 0.56$ in., $E_t = 1.13$ in., $\Delta H = -0.84$ in.

$O_g = 0.56 - 1.13 - (0.84)$

$O_g = 0.27$ in. $\simeq$ 960 gpm

winter (47.5-hour): $i_s = 0.27$ in., $E_t = 0.03$ in., $\Delta H = 0.24$ in.

$O_g = 0.27 - 0.03 - 0.24$

$O_g = \emptyset$

WATER-BUDGET STUDY

International Minerals & Chemical Corporation

The amount of waste-water inflow from IMC was measured directly with a Parshall flume that was installed in a channel below the spoil pile and above the pond. Most of the waste water passed through the flume, but some entered the lake through an auxiliary channel that branched off the main waste-water channel above the flume. The discharge of this channel was assumed to change proportionally with the discharge through the flume, since both had the same source, and both flowed a similar distance across the spoil pile. Total waste-water discharge into the lake is the sum of the flume flow and auxiliary channel flow.

The summer study was 56 hours in duration. During that time the measured discharge from the IMC refinery into Laguna Uno was 952,560 ft^3. This represents a steady flow rate of 2,120 gpm, which would have raised the water level in Laguna Uno by 0.37 inches during the 56-hour study period if there had been no water loss from the pond.

Total waste-water discharge into Laguna Uno for the 49-hour winter study was 1,436,094 ft^3. This is equivalent to a steady flow rate of 3,654 gpm, which would have produced a lake-level rise over the 710-acre surface of Laguna Uno of 0.56 inches during the 49-hour study period if there had been no water loss from the pond.

Discharge from springs into Laguna Uno over the 56-hour summer study period was 224,580 ft^3. This represents a flow of 500 gpm and would produce a lake-level rise of 0.09 inches. Similarily, 196,500 ft^3

of brine were discharged by springs into Laguna Uno during the 49-hour winter study. This is a flow rate of 500 gpm and would produce a lake-level rise of 0.08 inches.

Outflow from the IMC refinery could not be measured. Nevertheless the flume measurements show that there is a significant difference between summer and winter inflow to Laguna Uno from the spoil pile. This difference apparently is not due to refinery output, which is reported by the company to be nearly constant. Therefore, the difference is attributed to the change in the evaporation rate on the spoil pile from summer to winter. The exact amount of evaporation cannot be determined until accurate data are available which defines the amount of refinery discharge to the spoil pile.

Evaporation curves determined for Laguna Uno are given in Figures 6 and 7. The rates of evaporation ranged from 0.003 in/hr (inches per hour) to 0.039 in/hr and averaged 0.015 in/hr during the summer study. During the 56-hour summer study 0.83 inches of water were evaporated from the surface of Laguna Uno. During the winter the evaporation rate was much lower, ranging from zero to 0.004 in/hr. The average evaporation rate was 0.001 in/hr. Because of high humidity and near freezing temperatures recorded during the first day and a half of the winter study, the evaporation rate was near zero. The total amount lost to evaporation from Laguna Uno during the 49-hour period winter study was 0.04 inches.

The net changes in pond levels from beginning to end of the study periods are needed to determine the total water budget for Laguna Uno.

Measurements of pond level were made to the nearest 0.005 foot. At Laguna Uno, with a surface area of 710 acres, an error in measurement of ± 0.005 foot is equivalent to an additional flow of approximately 350 gpm into or out of the pond during the duration of the test. During the summer study the pond level of Laguna Uno dropped 0.39 inches. A rise of 0.09 inches was observed at the end of the winter study.

The values obtained from the water-budget equations indicate that Laguna Uno leaks. The leakage probably fluctuates seasonally; calculated values indicate higher leakage rates in winter. The summer rate of leakage was 110 gpm. Winter leakage was 3,300 gpm. Higher winter leakage can be attributed to the increased head in the ponds which occurs as a direct result of the lower winter evaporation rates.

The leakage enters the ground-water system and follows the ground-water gradient southward toward Salt Lake, the probable discharge point. The series of brine ponds may be hydrologically connected, and the ground-water-flow path from lake to lake may represent the most rapid path of ground-water movement toward Salt Lake.

The relationship between rate of evaporation and spoil-pile loss is shown clearly in Figures 6 and 7. The flume discharge decreased as the rate of evaporation increased, due to the increase in spoil-pile loss during periods of high evaporation.

The pond level of Laguna Uno remains relatively constant, ± 0.5 ft (table 3, IMC J Bar F stake) throughout the year, despite large seasonal fluctuations in evaporation rate and inflow rate of waste water (large amounts of plant discharge are lost on the spoil pile during periods of

high evaporation). This seems to indicate that an equilibrium with the local ground-water system has been established. Waste water discharged by IMC may often represent surplus water to the system, especially during the winter when evaporation rates are lower. The system maintains its equilibrium by varying the pond leakage rate.

Potash Company of America

Continuous records of refinery discharge are maintained by PCA and were made available to Geohydrology Associates, Inc., for the purposes of this study (written commun., PCA, 1978, 1979). The discharge values are used directly in the water-budget equations. Water loss due to evaporation or infiltration on the spoil pile could not be determined. Therefore, values of discharge into PCA pond used in the water-budget determination may be slightly higher than actual inflow, especially during periods of high evaporation.

The reported total waste-water discharge by PCA during the 57.3-hour period of the summer study was 916,715 ft^3. This is an average discharge rate of 1,995 gpm and would result in a lake-level rise of 0.56 inches over the 450-acre surface of the PCA pond. The winter study was 47.5 hours in duration. During that time 444,636 ft^3 of waste water was discharged by PCA. This is an average discharge rate of 1,167 gpm and would raise the PCA pond level 0.27 inches.

Evaporation rates from the PCA pond during the summer study ranged from 0.002 in/hr to 0.07 in/hr. A total of 1.13 inches evaporated from the pond in the 57.3-hour period. This is an average hourly rate of 0.02 inches of water lost per hour. Winter rates were much lower with an

average of 0.001 in/hr; the winter rates ranged from zero to 0.005 in/hr. During the period of study, a total of 0.03 inches of water were evaporated from the surface of the PCA disposal pond.

The leakage rate of the PCA pond is probably less than 500 gpm, and possibly much less.

The PCA pond level exhibits strong response to seasonal evaporation rate differences with the winter pond level in 1979 almost three feet higher than the 1978 summer level (table 3). A long-term cumulative increase in pond level may also be occurring. In the winter of 1979, the railroad tracks that cross PCA pond had to be relaid at a higher elevation to avoid inundation.

A large amount of natural ground-water inflow and outflow would tend to dampen the amplitude of lake-level changes. The large observed pond level changes suggest that PCA pond is not well integrated into the local ground-water system, and that ground-water movement out of and away from the PCA pond is relatively slow.

Leakage from PCA pond would follow the hydraulic gradient and move toward Clayton Lakes, which is suspected to be a ground-water discharge point.

The elevation of the PCA pond-water surface on February 13, 1979, was 3,188.2 feet. The surface of Clayton Wells pond is about 3,183 feet. The ground-water gradient between PCA and Clayton Wells is about two feet per mile.

The calculated summer rate of leakage was much higher than the winter leakage rate. Inflow values supplied by PCA represent the amount of water

discharged onto the spoil pile. Spoil-pile loss could not be measured and is treated as zero in the water-budget equation. Much of the water assumed to be lost by leakage during the summer study probably was lost by evaporation on the spoil pile. Consequently the lake-level decline attributed to leakage loss was probably caused by a pond inflow loss created by water lost to evaporation on the spoil pile.

The winter rate probably gives a better idea of actual leakage. During much of the winter study period, the evaporation rate was near zero.

Spoil pile loss was small. Therefore inflow values were more accurate, and the resulting leakage rate is probably more representative.

Other Potash Refineries

Summer leakage for the period of study for IMC was 0.55 gpm/acre. Winter leakage for the period of study was 3.9 gpm/acre. Due to the meteorological conditions which prevailed during the two study periods, these rates are believed to represent minimum and maximum leakages.

Hydrologic conditions at Duval Corporation, AMAX Chemical Corporation, Mississippi Chemical Corporation, and Kerr-McGee Chemical Corporation refineries are believed to be similar to those at IMC. Therefore the leakage rates measured at IMC have been used to approximate the leakages at these refineries for the study period (table 4). Insufficient information is available to approximate leakages from the National Potash Company disposal pond.

It is not possible with the available data to meaningfully rank the disposal ponds as sources of ground-water pollution, except to point out that the PCA pond, as a ground-water discharge point, is highly unlikely to be a source of pollution.

Table 4. Evaporation, flow, and seepage rates from potash refineries.

Name of Refinery	Starting date	Formation used for disposal	Area of disposal ponds (acres)	Measured summer evaporation rate (gpm)	Measured winter evaporation rate (gpm)	Calculated summer seepage (gpm)	Calculated winter seepage (gpm)	Rate of ground-water movement (ft/yr)	Maximum distance of waste movement (feet)
Potash Company of America	1934	Prfn	450	3,510	152	960*	0	0	0
Mississippi Chemical Corp.	1940	PTrdl	157	1,224	53	86	610	5.4	277
International Mineral and Chemical	1947	Prfn	710	4,750	260	393	2,800	?	?
Duval Corp.	1951	PTrdl	62	480	21	34	240	5.4	152
AMAX Chemical Corporation	1952	Prfn	90	700	30	50	350	232	6,267
National Potash	1957	Qal	?	?	?	?	?	47	1,034
Kerr-McGee Chemical Corporation	1965	PTrdl	157	1,224	53	86	610	9.3	130

*Spoil-pile evaporation loss

PRECIPITATION AND WATER-TABLE FLUCTUATION

Water-table fluctuation in response to precipitation is a good indicator of both the rate of ground-water movement and the amount of infiltration of meteoric waters. These two factors affect the speed with which pollutants are dispersed and the concentration of the pollutants in ground water.

To study the relationship between precipitation and water-table fluctuation, Geohydrology Associates monitored 13 observation wells and 25 rain gages in Nash Draw and Clayton Basin about once per month from March 1978 to March 1979 (fig. 14; appendix).

Evapotranspiration is the loss of ground and surface water through evaporation from soil and transpiration from the leaves of plants. Potential evaportranspiration is an estimate of actual evapotranspiration based on measurements that quantify the atmospheric capacity for evaporating water from an exposed body of water.

Potential evapotranspiration is the best estimate of the amount of water that may evaporate from the soil and transpire from vegetation with unlimited ground-water supplies (Tuan, 1973, p. 112). This description implies an area of lush vegetation and soils saturated with water. Obviously the study area is too arid for a computed value of potential evapotranspiration in the area to correspond closely with actual evapotranspiration. However, peaks and ebbs in potential evapotranspiration rates should correspond to peaks and ebbs in actual evapotranspiration rates in the study due to the abundance of phreatophytes.

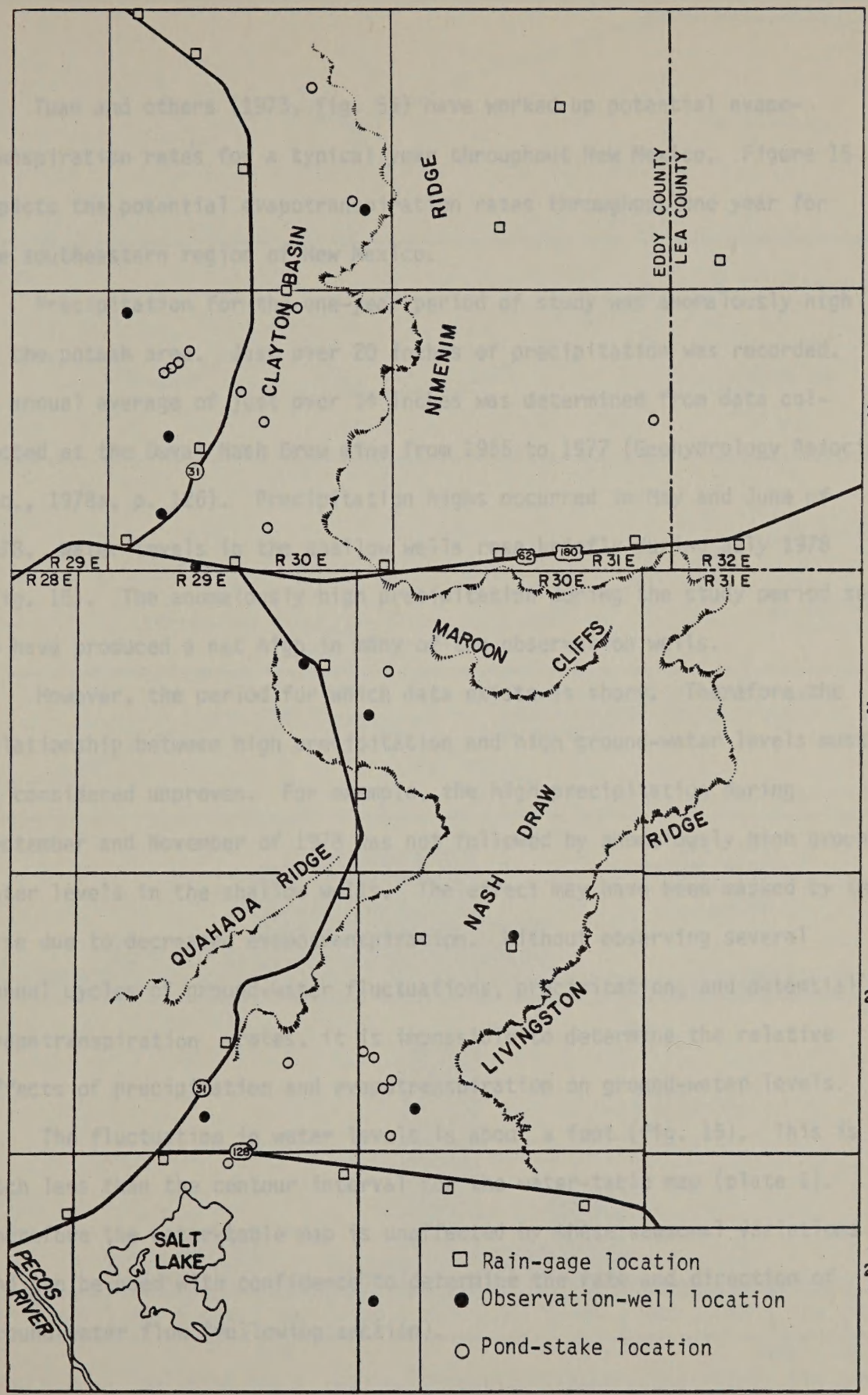
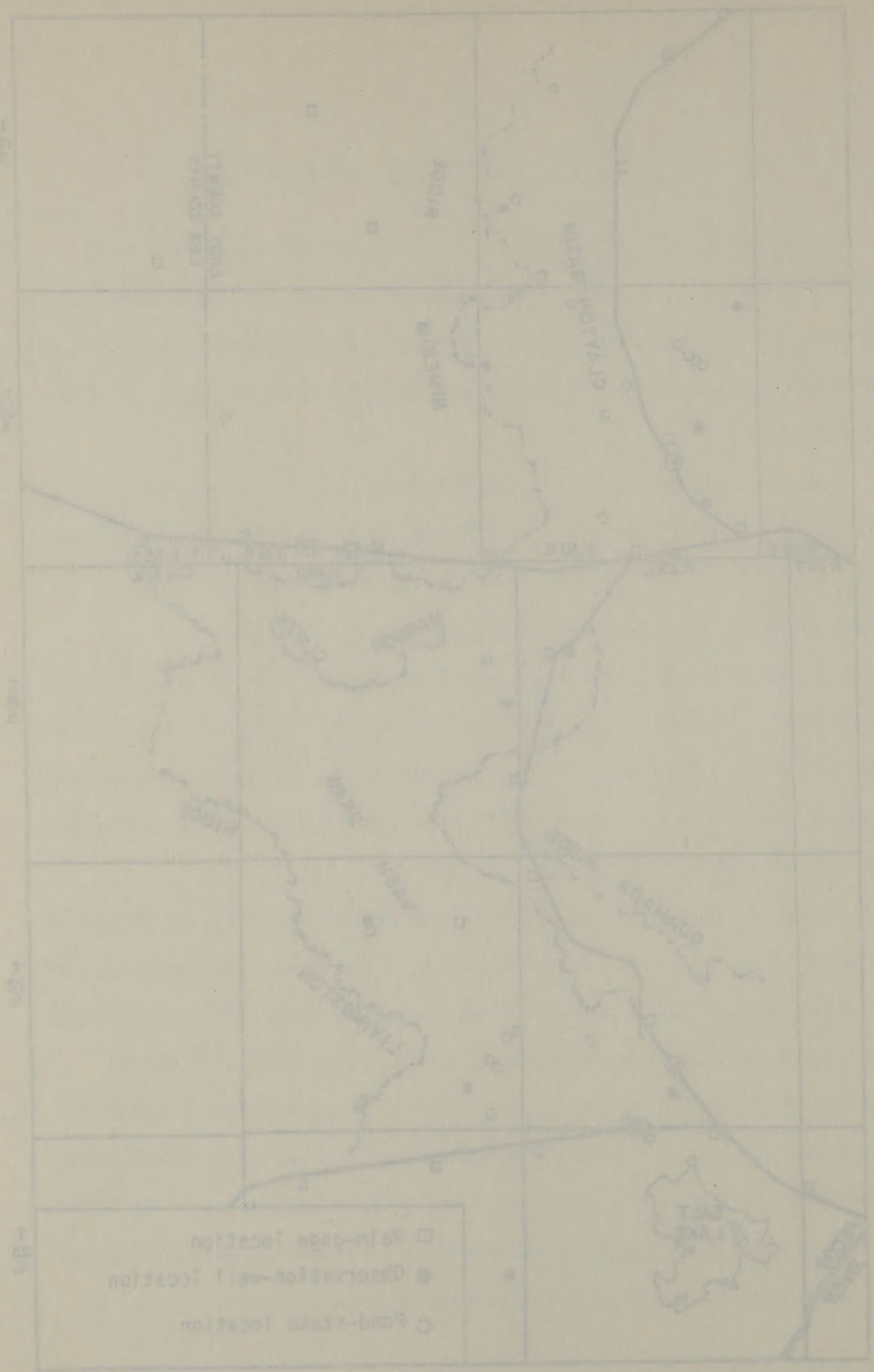


Figure 14. Map showing rain gages, observation wells, and pond stakes.



Tuan and others (1973, fig. 55) have worked up potential evapotranspiration rates for a typical year throughout New Mexico. Figure 15 depicts the potential evapotranspiration rates throughout one year for the southeastern region of New Mexico.

Precipitation for the one-year period of study was anomalously high in the potash area. Just over 20 inches of precipitation was recorded. An annual average of just over 14 inches was determined from data collected at the Duval Nash Draw mine from 1955 to 1977 (Geohydrology Associates, Inc., 1978a, p. 126). Precipitation highs occurred in May and June of 1978. Water levels in the shallow wells rose briefly during July 1978 (fig. 15). The anomalously high precipitation during the study period seems to have produced a net high in many of the observation wells.

However, the period for which data exists is short. Therefore the relationship between high precipitation and high ground-water levels must be considered unproven. For example, the high precipitation during September and November of 1978 was not followed by anomolously high ground-water levels in the shallow wells. The effect may have been masked by the rise due to decreased evapotranspiration. Without observing several annual cycles of ground-water fluctuations, precipitation, and potential evapotranspiration rates, it is impossible to determine the relative effects of precipitation and evapotranspiration on ground-water levels.

The fluctuation in water levels is about a foot (fig. 15). This is much less than the contour interval for the water-table map (plate 1). Therefore the water-table map is unaffected by these seasonal variations and can be used with confidence to determine the rate and direction of ground-water flow (following section).

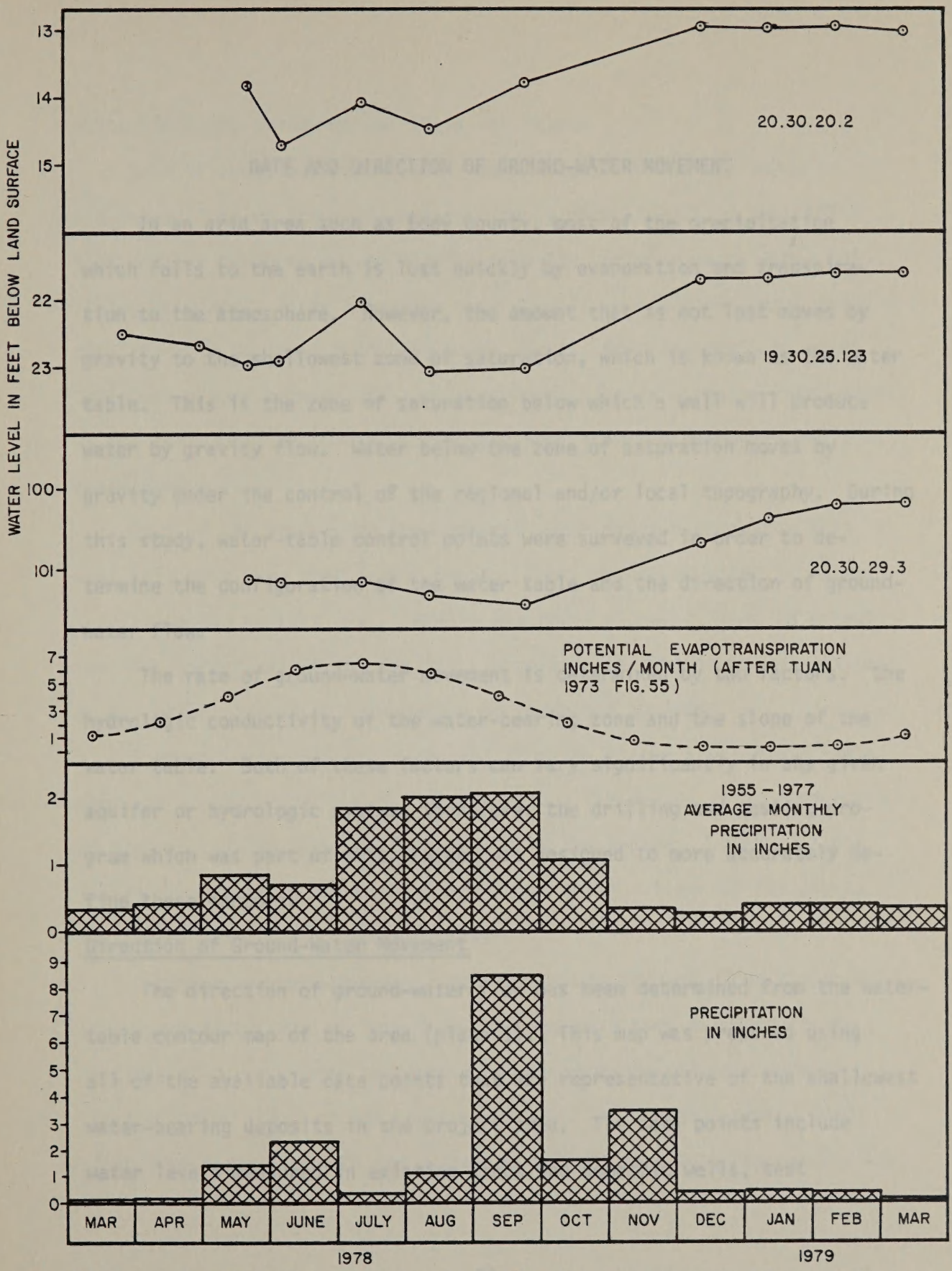
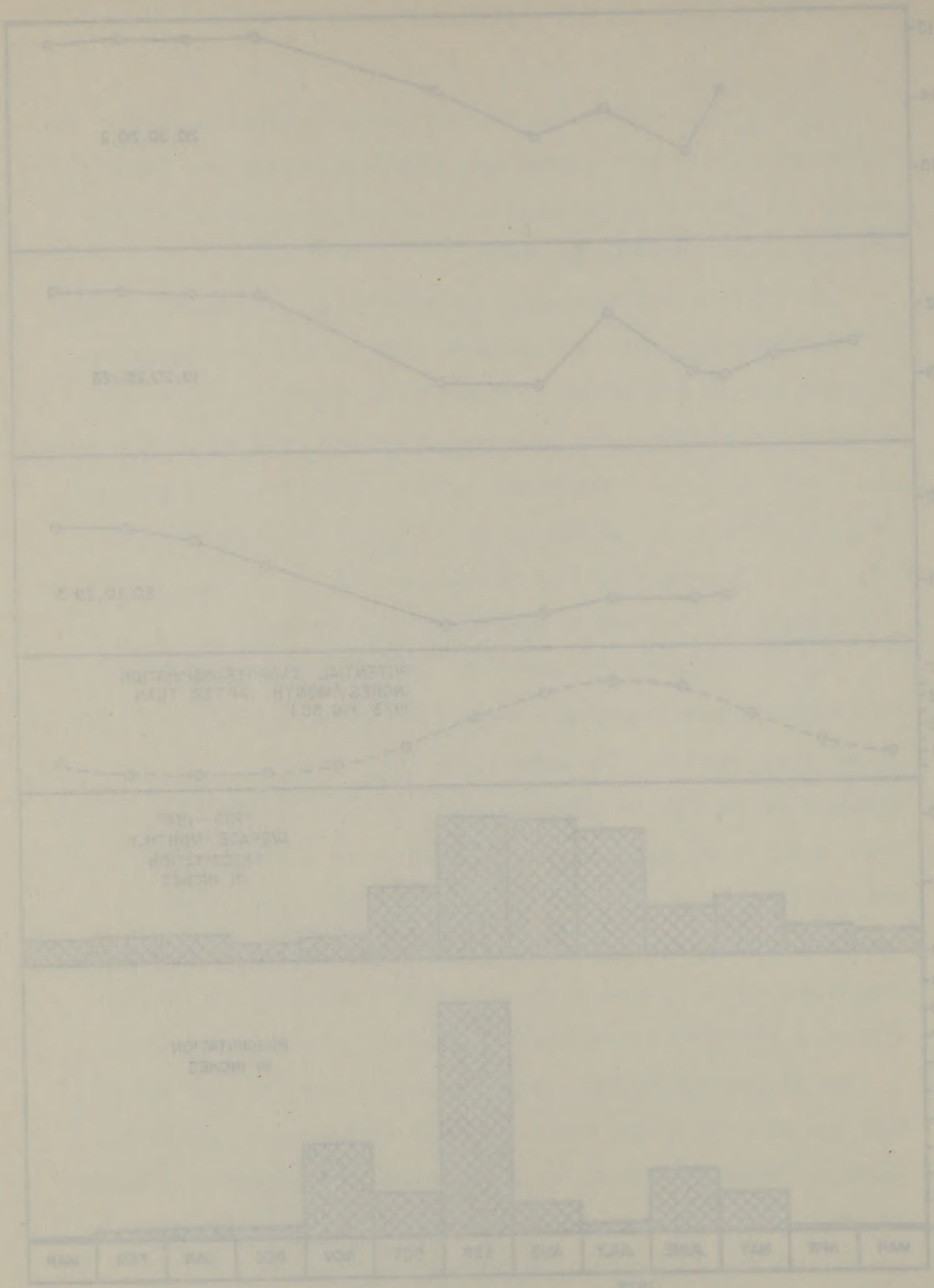


Figure 15. Selected water levels, potential evapotranspiration, and precipitation graphs for the study area, March 1978-March 1979.



RATE AND DIRECTION OF GROUND-WATER MOVEMENT

In an arid area such as Eddy County, most of the precipitation which falls to the earth is lost quickly by evaporation and transpiration to the atmosphere. However, the amount that is not lost moves by gravity to the shallowest zone of saturation, which is known as the water table. This is the zone of saturation below which a well will produce water by gravity flow. Water below the zone of saturation moves by gravity under the control of the regional and/or local topography. During this study, water-table control points were surveyed in order to determine the configuration of the water table and the direction of ground-water flow.

The rate of ground-water movement is determined by two factors: the hydrologic conductivity of the water-bearing zone and the slope of the water table. Both of these factors can vary significantly in any given aquifer or hydrologic system; therefore, the drilling and testing program which was part of this project was designed to more accurately define these factors.

Direction of Ground-Water Movement

The direction of ground-water flow has been determined from the water-table contour map of the area (plate 1). This map was prepared using all of the available data points that are representative of the shallowest water-bearing deposits in the project area. The data points include water levels measured in existing stock and domestic wells, test

holes, springs, and perennial ponds and lakes.

Several anomalous water levels were identified and are shown on the maps. Some of these are believed to be water levels in test holes that had not returned to equilibrium with the regional water table following drilling. Other anomalous water levels probably represent artesian conditions in aquifers below the water table. Only the regional water table was mapped because this surface, which locally contains fresh water, is the hydrologic feature that has been most affected by potash-refining operations.

East of the study area the regional water table slopes from east to west into Nash Draw and Clayton Basin. Thus, the ground water is moving into these two depressions. Locally the regional water table intersects the land surface along the face of Livingston and Nimenim Ridges where ground water discharges as a series of seeps and springs.

A ground-water divide is present from the vicinity of Laguna Plata westward to the south end of Clayton Basin. The divide is located north of Highway 62-180 and roughly parallel to the highway. North of this divide the ground water moves into Clayton Basin. South of the divide the ground water moves into Nash Draw.

A pronounced ground-water recharge area is present along the axis of Quahada Ridge west of Nash Draw, and there is some evidence to indicate that ground-water recharge also occurs along the west side of Clayton Basin. West of the two depressions, the regional ground water flows from north to south and ultimately discharges into the Pecos River.

Rate of Ground-Water Movement

The method of drilling and testing that was used during this investigation has been described in a preceeding section of this report. In addition to the coefficients of transmissivity and storage that were determined for test holes, the drill cuttings were examined in order to determine the lithologic characteristics of the formations penetrated. The sample logs are included in the Appendix of this report. Also, the Water Resources Division of the U. S. Geological Survey made geophysical (gamma) logs of most of the test holes (appendix). These various logs enabled determination of the various formations that were drilled and also the hydrologic characteristics of these formations.

Quaternary deposits exhibited the highest average transmissivities of the units encountered, ranging from 14 ft^2/day to 470 ft^2/day and a mean of 255 ft^2/day (table 5). Lithologies ranged from coarse sand and gravel to medium-to-fine sands laid down as lake deposits, alluvium, and valley fill. Often these units contained brine.

Triassic deposits probably yielded water from thin, fine-grained sandstone stringers within a thick sequence of clayey shale and siltstone. Tranmissivities for Triassic units ranged from 0.44 ft^2/day to 35 ft^2/day and a mean of 9.8 ft^2/day.

Five wells were completed in the Dewey Lake Redbeds. Transmissivity values ranged from 0.06 ft^2/day to 12 ft^2/day and a mean of 4.9 ft^2/day. Transmissivities were generally low because the aquifer is composed of silty shale with some very-fine-grained sands. Thin-bedded

Table 5. Geohydrologic characteristics for test holes in the Clayton Basin and Nash Draw area.

Formations: Qal, Quaternary alluvium; Qp, Quaternary playa lake deposits; Qvf, Quaternary valley fill (Gatuna?); Tr, Triassic, TPrdl, Permian or Triassic Dewey Lake Redbeds; Prfn, Permian Rustler Formation, Forty-niner Member; Prt, Permian Rustler Formation, Tamarisk Member; Prc, Permian Rustler Formation, Culebra Dolomite Member.

Location	Lithology	Formation	Transmissivity	Hydraulic Conductivity (ft/day)	Flow Rate (ft/yr)	Porosity (%)
19.30. 5.32	sand	Qvf	14	0.15	6.0	0.20
20.30.15.31	fine sand	Qp	470	26.11	52.5	.20
32.17.13	calcareous sand	Qp	350	6.63	47.0	.20
23.29.18.14	sand and gravel	Qal	185	6.60	21.5	.20
20.31. 2.34	silty shale; sand	Tr. undiff.	.97	.06	73	.30
27.24	siltstone	Tr. undiff.	.44	.04	.18	.30
32.22.33	siltstone	Tr. undiff.	5	.50	4.3	.30
21.31. 3.22	silty shale	Tr. undiff.	35	1.12	9.3	.30
19.30.35.23	shale with siltstone	PTrdl	9.4	1.04	17.7	.30
20.30.23.11	silty calcareous	PTrdl	12	1.20	7.0	.30
28.4	silty shale, anhydrite	PTrdl	.06	.003	.02	.30
29.33	silty shale, some gypsum in lower hole	Trdl	3.0	.38	2.1	.30
23.29.26.12	siltstone, shale	Trdl and Prfn	.13	.02	.03	.30
[a]19.30.24.133	siltstone	Prfn and PTrdl	251	25.1	232.0	.15
33.31	siltstone, gypsum	Prfn	35	1.59	4.0	.15
[b]20.29.25.33	gypsum	Prfn	330	3.90	42.0	.15
23.29.28.41	gypsum	Prt	40	5.0	24.2	.12
21.29.25.423	dolomite (?)	Prc (?)	20	-	-	-
23.29.20.33	dolomite/limestone	Prc (?)	135	12.3	105.0	.12

[a] Probably fractured
[b] Possibly in fracture zone near collapse

gypsum was also encountered in the lower sections of some of these holes. The Dewey Lake Redbeds reportedly do not contain gypsum (Brokaw and others, 1972, p. 51), so the top of the Rustler Formation might have been penetrated in the holes where gypsum was encountered.

Rocks of the Rustler Formation provided water to six test wells. The mean transmissivity value was 136 ft^2/day. The Rustler contains four members in the Nash Draw area. Three members were penetrated in the drilling program: the Forty-niner Member, the Tamarisk Member, and the Culebra Dolomite Member. Three wells tapped the Forty-niner Member. This unit is 40 to 60 feet thick and consists of broken and slumped gypsum. Transmissivities ranged from 35 ft^2/day to 330 ft^2/day and a mean of 205 ft^2/day. As transmissivity is increased by fracturing of the aquifer, the two values over 250 ft^2 per day might be due to local fracturing.

One well tapped the Tamarisk Member. This unit is about 115 feet thick and is primarily gypsum and anhydrite. A transmissivity of 40 ft^2/day was measured.

Two wells probably tap the Culebra Dolomite. One aquifer test on an existing well (21.29.25.423) produced a transmissivity value of 20 ft^2/day. Lithologic logs and gamma logs are not available on this hole. However, the owner reported that during drilling, "strong" water was encountered when a limestone layer was penetrated, at some depth greater than 200 feet. The second test in the Culebra Dolomite was run on a well south of Salt Lake (23.29.20.33). Saline water was encountered in dolomite at a depth of 50 feet. Water rose to within 27 feet of the surface indicating that

the aquifer was confined. The transmissivity determined from an aquifer test on this well was 135 ft^2/day.

In any given formation and aquifer, the rate of ground-water movement, or the velocity, V, is directly proportional to the gradient of the water table, I, and to the hydraulic conductivity of the aquifer, K. It is inversely proportional to the porosity, θ, of the aquifer. The velocity is expressed by the formula $V = KI/\theta$.

The gradient of the water table was determined from water-table contour map (plate 1). The coefficient of transmissivity, divided by the aquifer thickness, equals the hydraulic conductivity, K. The gamma and sample logs of each well were used to determine the thickness of the water-bearing zones in each test well. Thus, the coefficient of transmissivity was determined from the aquifer test, and the aquifer thickness was determined from the logs of the test hole.

The techniques used in aquifer testing did not include a means of directly measuring aquifer porosity; however, previous ground-water studies in the Nash Draw area provided these data. A porosity of 12 percent was determined for the Culebra Dolomite Member of the Rustler Formation (Grove and Beetem, 1971, p. 133). A general value for average porosity of the Rustler Formation suggested by Hiss (unpublished data from Logan, S. E., 1976) is 15 percent.

Aside from the Rustler Formation, which has been the object of several previous hydrologic investigations, little data exist on the hydraulic properties of other geologic units tested in the study area, thus porosity values assigned to the Dewey Lake Redbeds, 30 percent, the

Triassic undifferentiated, 30 percent, and the Quaternary sands and gravel, 20 percent, were based on comparison of the above formations with other aquifers of similar lithology and hydrology for which porosity values had been determined.

In general there is a close correlation between the coefficient of transmissivity and the flow rate of ground water in the various formations (table 4). The highest flow rates are consistently found in the Rustler Formation; the lowest rates generally are present in the Dewey Lake Redbeds. In those areas where the formations have been deformed by collapse along the major ridges, the secondary permeability created by extensive fracturing has produced higher rates of ground-water movement.

Migration of Refinery Waste

Most of the water that is used in the refining of potash is imported from aquifers located outside the project area. International Minerals Corporation pipes water from wells tapping the Capitan limestone near Carlsbad, whereas the other refineries utilize water obtained from the Ogallala aquifer in Lea County. The total amount of water that is imported annually by the refineries is estimated to be about 19,760 acre-feet per year (Geohydrology Associates, Inc., 1978). Of this total, 5,066 acre-feet per year is subsequently discharged by refineries located north of the ground-water divide in Clayton Basin. Approximately 9,248 acre-feet per year is discharged as brine by refineries located in Nash Draw. The Duval refinery is located very near the ground-water divide, and its discharge may enter both depressions. In addition to the imported water, AMAX and Mississippi Chemical supplement their imported water with

production from wells tapping saline-water aquifers near the plant sites.

Most of the water used in processing potash ore is discharged by the refineries as saturated brine containing as much as 30 percent solids in the form of suspended clay. The exact amount of discharged water is difficult to determine since most of the plants do not monitor the discharge. In addition, the amount of solids varies with the brine temperature and viscosity. Several of the companies estimate that the amount of brine discharge is approximately 75 percent of the total imported water. Thus approximately 10,700 acre-feet of saturated brine is released into the potash area each year.

The brine that is released by the refineries creates an anomalous condition in the hydrologic system of Clayton Basin and Nash Draw. With the exception of IMC, located in Nash Draw, all of the refineries pond the brine with earthen dams located near the individual refineries. In the Water-Budget section of this report, it has been shown that the evaporation rate during the cooler parts of the year is not sufficient to consume all of the water released by the refineries. Surface leakage from the brine ponds is generally not a problem, therefore most of the ponds leak water to the ground-water aquifers.

U. S. Potash Company. Following the discovery of the mineral sylvite in the Snowden-McSweeney McNutt No. 1 well in 1925, U. S. Potash Company began an exploratory drilling program. Their first shaft for the underground mining of potash was completed in January 1931. The ore produced by this mine was processed at a refinery constructed in sec. 18, T. 23 S., R. 29 E., and the tailings were emptied into Salt Lake (fig. 16). There

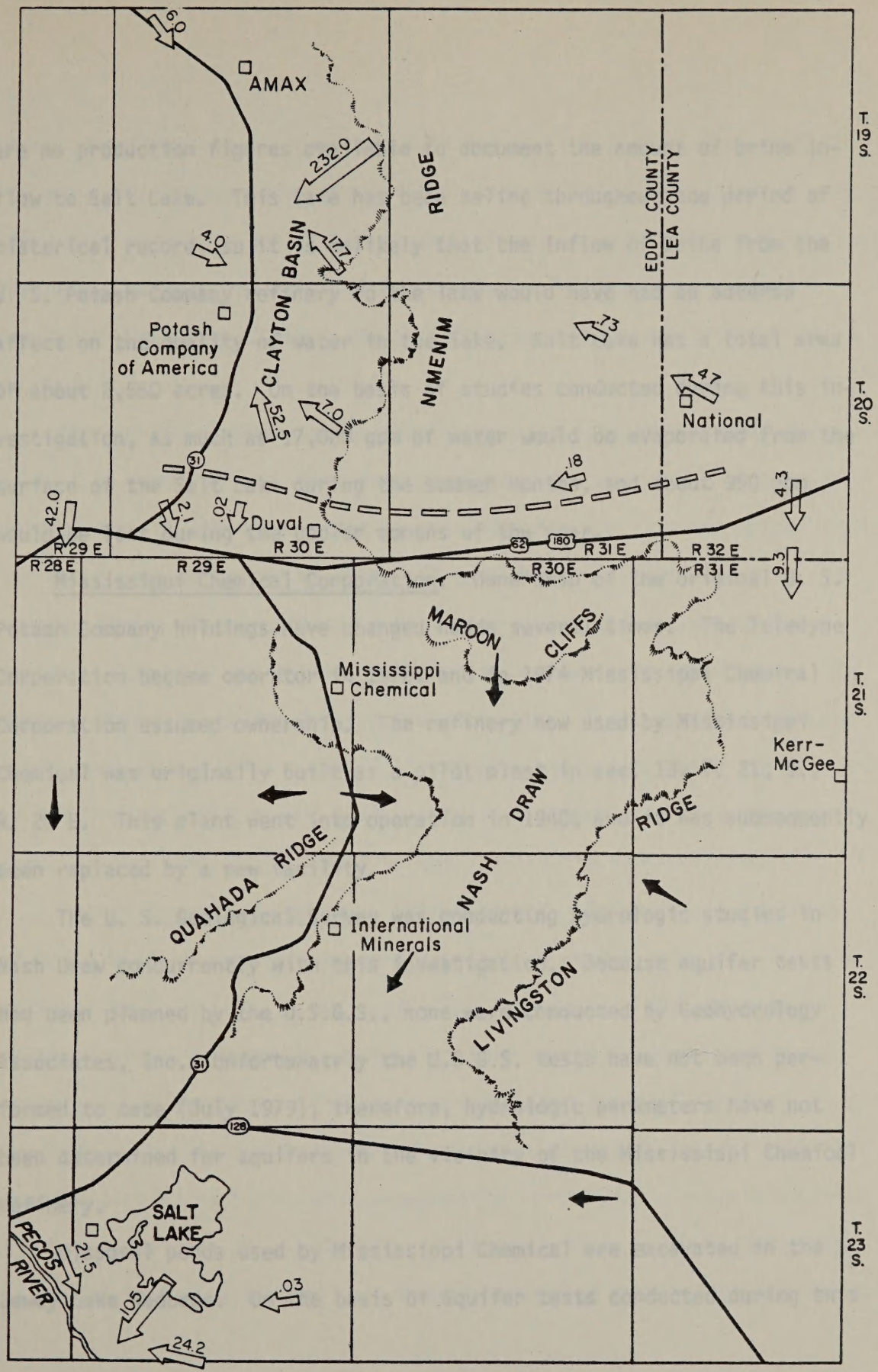
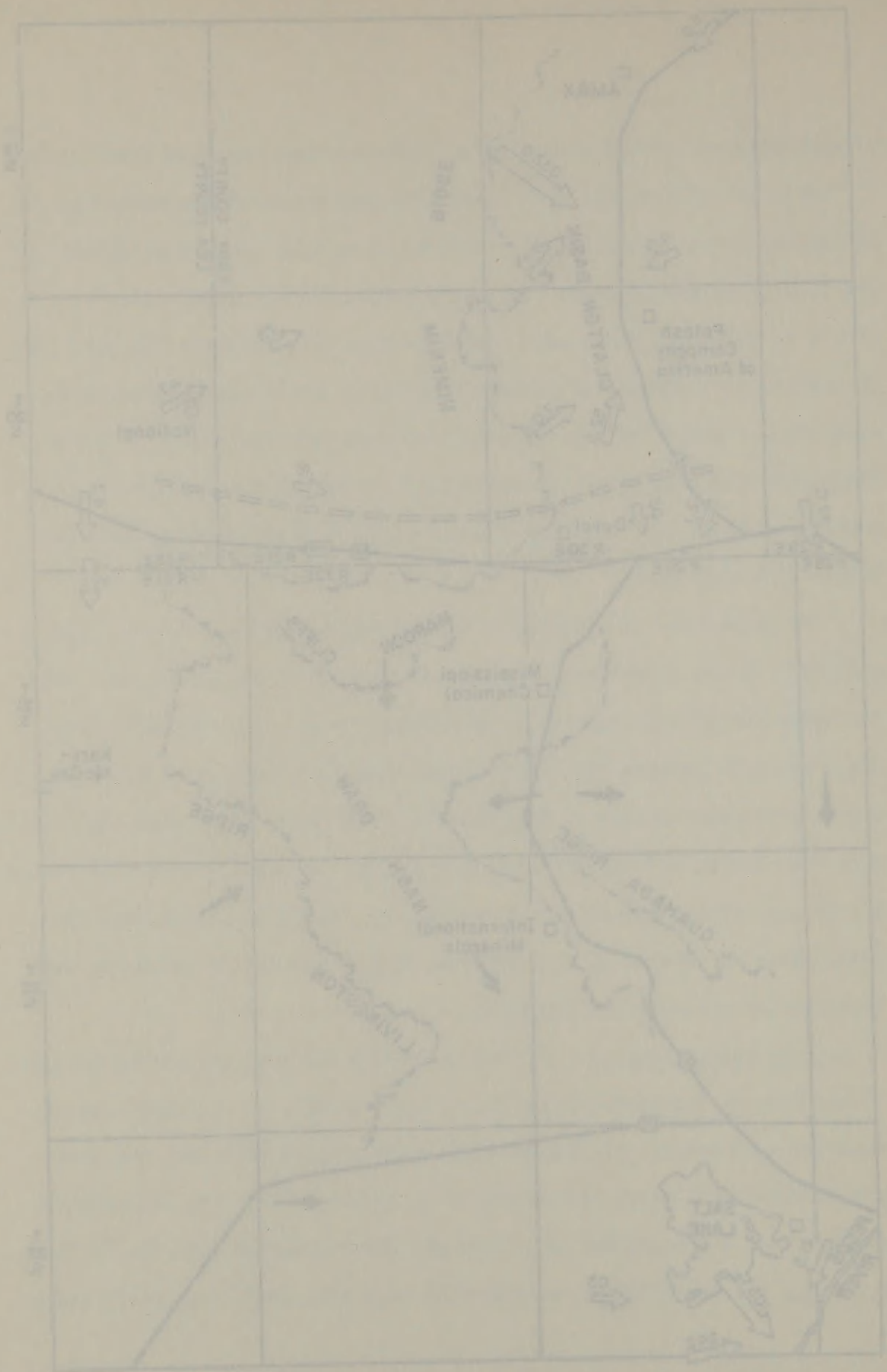


Figure 16. Direction and rate of ground-water flow.
Numbers are rate of flow in feet/year;
dashed line shows ground-water divide.



are no production figures available to document the amount of brine inflow to Salt Lake. This lake has been saline throughout the period of historical record, so it is unlikely that the inflow of brine from the U. S. Potash Company refinery to the lake would have had an adverse affect on the quality of water in the lake. Salt Lake has a total area of about 2,560 acres. On the basis of studies conducted during this investigation, as much as 17,000 gpm of water would be evaporated from the surface of the Salt Lake during the summer months, and about 950 gpm would be lost during the cooler months of the year.

Mississippi Chemical Corporation. Ownership of the original U. S. Potash Company holdings have changed hands several times. The Teledyne Corporation became operator in 1972, and in 1974 Mississippi Chemical Corporation assumed ownership. The refinery now used by Mississippi Chemical was originally built as a pilot plant in sec. 13, T. 21, S., R. 29 E. This plant went into operation in 1940, and it has subsequently been replaced by a new facility.

The U. S. Geological Survey was conducting hydrologic studies in Nash Draw concurrently with this investigation. Because aquifer tests had been planned by the U.S.G.S., none were conducted by Geohydrology Associates, Inc. Unfortunately the U.S.G.S. tests have not been performed to date (July 1979); therefore, hydrologic parameters have not been determined for aquifers in the vicinity of the Mississippi Chemical refinery.

Disposal ponds used by Mississippi Chemical are excavated in the Dewey Lake Redbeds. On the basis of aquifer tests conducted during this

study, the flow rate in these deposits ranged from 17.7 ft/year to 0.02 ft/year; the average flow rate was 5.4 ft/year (table 5). Assuming that these flow rates are applicable to the redbeds at the Mississippi Chemical refinery, leakage from these disposal pits would have migrated east-southeast a maximum of about 277 feet from the pond since refining began in 1940.

Part of the refinery brine that is emptied into the disposal ponds is lost by evaporation. The Mississippi Chemical disposal ponds had a surface area of 157 acres prior to mid-1978 when the size was significantly increased. Based on the original 157-acre size, 1,224 gpm would be evaporated during the summer and about 53 gpm would be lost during the winter. This does not include evaporation loses on the spoil pile. The average annual discharge is reported to be about 1,300 gpm (Geohydrology Associates, Inc., 1978, p. 75). Therefore, during the summer months, most of the Mississippi Chemical brine is lost by evaporation on a 157-acre pond, however very little would be lost during the winter months.

Potash Company of America. Potash Company of America, a Division of Ideal Basic Industries, began production of potash in 1934. The PCA refinery is in sec. 4, T. 20 S., R. 30 E. (plate 1). The refinery is within a closed topographic depression that roughly coincides with the center of Clayton Basin. This is a ground-water basin of internal drainage. Therefore all of the refinery discharge into the PCA pond is trapped within the basin, and consequently it is totally evaporated from the ponds and from the spoil pile. This evaporation cycle is described in detail in the section of this report pertaining to the PCA Water-Budget

Study, page 43. In addition to the refinery losses, some surface runoff and spring discharge also is evaporated from the PCA pond each year.

Duval Corporation. Dulval Sulfur and Potash Company, now Duval Corporation, is a Division of Pennzoil, Inc. The Duval refinery is in sec. 35, T. 20 S., R. 30 E.; production began in 1951. Disposal ponds used by Duval are located near the axis of the ground-water divide that separates Clayton Basin and Nash Draw. Therefore it is difficult to determine the direction of flow by leakage from the ponds. The principal direction of flow probably is toward Nash Draw, however some leakage may flow northward.

The Duval disposal ponds are excavated in Dewey Lake Redbed deposits. A slug test was made on a well located about a half mile northwest of the pond in sec. 28, T. 20 S., R. 30 E. The flow rate determined for the Dewey Lake deposits at the well was 0.02 ft/year. This value is so low that it indicates virtually no flow. The average flow rate for these deposits is 5.4 ft/year. If this value is assumed to be accurate for the vicinity of the Duval disposal ponds, leakage would have migrated a maximum distance of about 152 feet since refining began in 1951.

The Duval disposal pond has a surface area of approximately 62 acres (Geohydrology Associates, Inc., 1978, p. 70). Summer evaporation rates from a pond of this size would be about 480 gpm, whereas winter evaporation would be about 21 gpm. There would also be evaporation losses from the spoil pile. The average inflow to the pond is 790 gpm.

AMAX Chemical Corporation. Southwest Potash Company began production in 1952. The company was subsequently bought by AMAX Chemical Corporation. The AMAX refinery is located near the north end of Clayton Basin in sec. 9 and 10, T. 19 S., R. 30 E.

The brine pond used by AMAX is excavated in the Rustler Formation. It reportedly has a surface area of about 90 acres, which would evaporate approximately 700 gpm of water during the summer months and approximately 30 gpm during the winter. Additional evaporation losses would occur on the spoil pile.

Hydrologic characteristics of the Rustler Formation have been tested in several wells located near the AMAX pond. Computed rates of flow ranged from 4.0 ft/year to a high of 232 ft/year (fig. 16). The high value probably represents a well tapping a fractured zone. If this flow rate of 232 ft/year is used to determine the impact of leakage from AMAX, the refinery brine has migrated southeastward a total distance of about 6,267 feet. The average flow rate for the Rustler Formation is 81.5 ft/year and would be more representative of the deposits. Based on the 27-year history of the AMAX refinery, the leakage would have migrated about 2,200 feet.

National Potash Company. A Division of Freeport Sulphur, National Potash has a refinery in sec. 18, T. 20 S., R. 32 E. which began operation in January 1957. Brine discharge from this plant is emptied into Williams Sink and Laguna Plata. Both of these topographic depressions are located on Triassic shales; however, a test hole located in sec. 17,

T. 20 S., R. 32 E. penetrated about 42 feet of Quaternary sand overlying the shale.

The various salt lakes in the vicinity of the National refinery probably represent natural ground-water discharge points. Stratigraphically Williams Sink, Laguna Plata, Laguna Gatuna, and Laguna Tonto are all several hundred feet above the shallowest salt deposits in the Rustler Formation (Geohydrology Associates, Inc., 1978, p. 78). Williams Sink and Laguna Plata have been used for disposal of refinery waste, but Laguna Gatuna and Laguna Tonto contain natural salt deposits. The regional water-table contour map (plate 1) shows that ground water moves west and south from the Williams Sink-Laguna Plata area, and several springs have been mapped along the edges of Laguna Plata. The presence of these springs, as well as the configuration of the water table, substantiate that the lakes and sinks in this area are natural ground-water discharge points similar to Clayton Basin. The natural salt deposits in these lakes represent the residue from evaporated ground water and surface inflow.

Assuming that Williams Sink is a natural ground-water discharge point, the refinery waste probably remains in the sink where it completely evaporates. If movement does occur, it would be in a west-northwestwardly direction at a rate of about 47 ft/year, as determined from a well test in the vicinity of National (fig. 16). Therefore, during the 22-year history of the refinery, brine would have migrated a maximum distance of about 1,034 feet.

Kerr-McGee Chemical Corporation. The refinery operated by Kerr-McGee began production in 1965. Its location, sec. 25, T. 21 S., R. 32 E., is in the northeast corner of Nash Draw. Refinery wastes are discharged into two ponds that have been excavated in beds near the contact of the Dewey Lake Redbeds and the overlying Triassic shales. In addition, some refinery waste is piped to Laguna Toston. The total surface area of these three discharge sites is 157 acres. During the summer months, these ponds would have the capability of evaporating about 1,225 gpm, whereas in the winter the evaporation rate would be about 53 gpm. This does not include spoil-pile evaporation loses. The average discharge from the Kerr-McGee refinery is about 890 gpm.

Two aquifer tests were conducted on wells tapping the Triassic deposits northeast of the Kerr-McGee disposal site (fig. 16). The results of these tests indicate a flow rate of 4.3 to 9.3 ft/year. Using the upper value of flow rate, and a refinery history of 14 years, the leakage from these ponds would have moved a total distance of about 130 feet.

International Minerals & Chemical Corporation. All of the refinery discharge from International Minerals & Chemical Corporation is released into the headwaters of Laguna Uno which is in parts of sections 24 and 25, T. 22 S., R. 29 E. and adjoining sections. Evaporation rate and water loss from this lake have been studied in detail during this investigation and the preceeding study (Geohydrology Associates, Inc., 1978).

Discharge records of brine from the IMC refinery are not available. However, according to the New Mexico State Engineer Office in Roswell,

the amount of water imported by IMC during 1977 was 5,233 acre-feet. This is equivalent to 3,244 gpm. Not all of this water is released as brine. Some of the imported water is lost during the refining process, and some loss occurs by evaporation on the spoil pile. During most of the evaporation study at Laguna Uno, the measured discharge was quite similar to the imported quantity. This suggests that refinery losses are minimal, and spoil-pile loss is small, at least during periods of low to moderate evaporation.

There is no surface outlet for Laguna Uno. Nevertheless, it is the first of a chain of lakes which extend from the point of IMC's discharge to Salt Lake (fig. 17). The surface elevations of these lakes show a consistent drop along the route of surface-water flow. In addition, Lindsey Lake and Tamarisk Flats are also below the elevation of Laguna Uno. The evaporation studies have shown that large quantities of water are evaporated from lakes during the warm weather, and the drainage area of each lake is not sufficient to account for the amount of brine present. Therefore the level in these lakes must be maintained, at least in part, by another water source. The only available source is refinery discharge from International Minerals & Chemical Corporation.

Nash well (23.30.6.420) was completed for use in stock watering prior to 1935. Subsequently the level of Laguna Quatro has risen to the point that this well was completely inundated by 1977. Likewise, the J Bar F well (22.30.20.240) supplied water for stock at Laguna Uno. According to Hendrickson and Jones (1952, p. 134-135), the water level in this well was 134.0 feet below land surface on March 17, 1948. The water level is

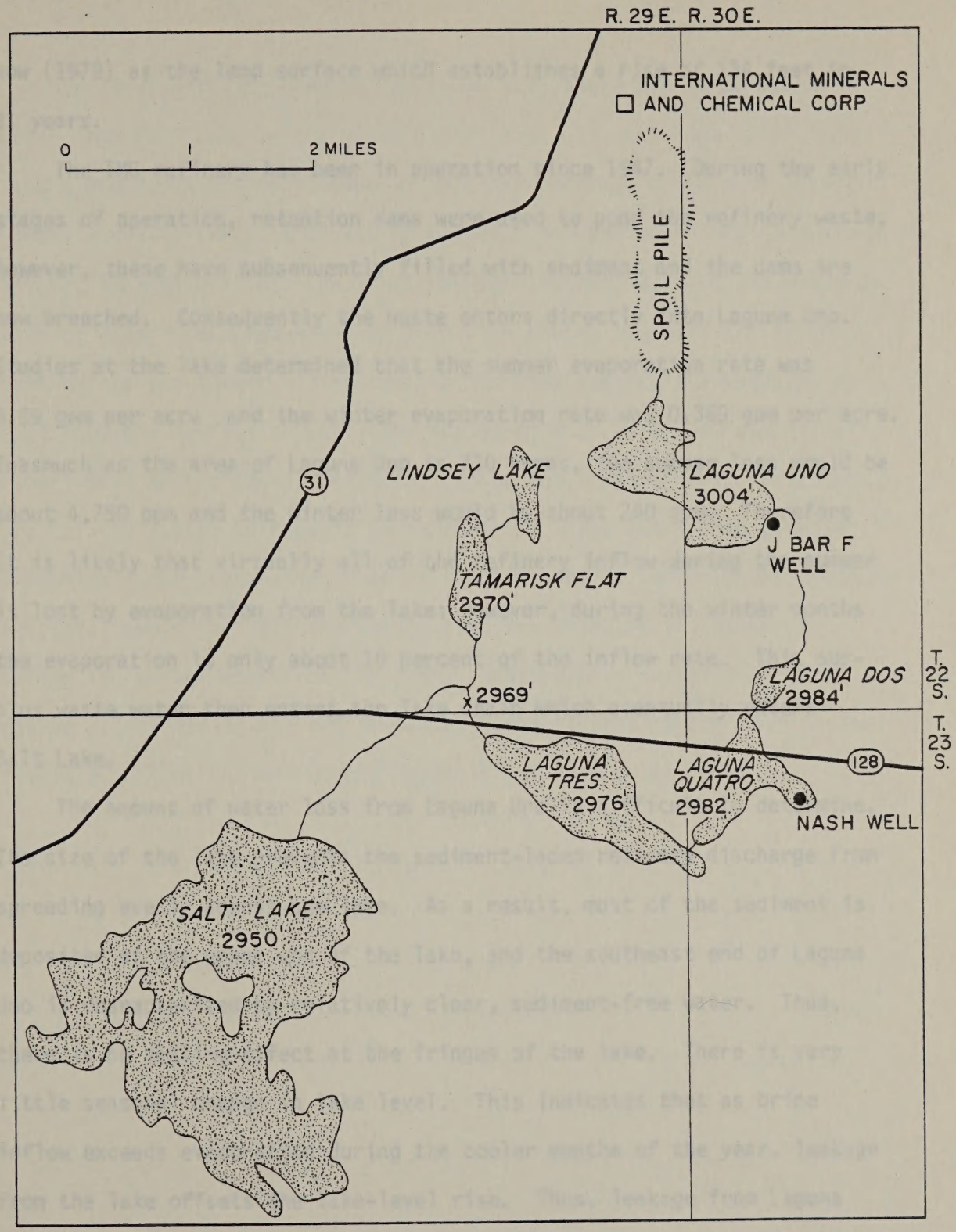
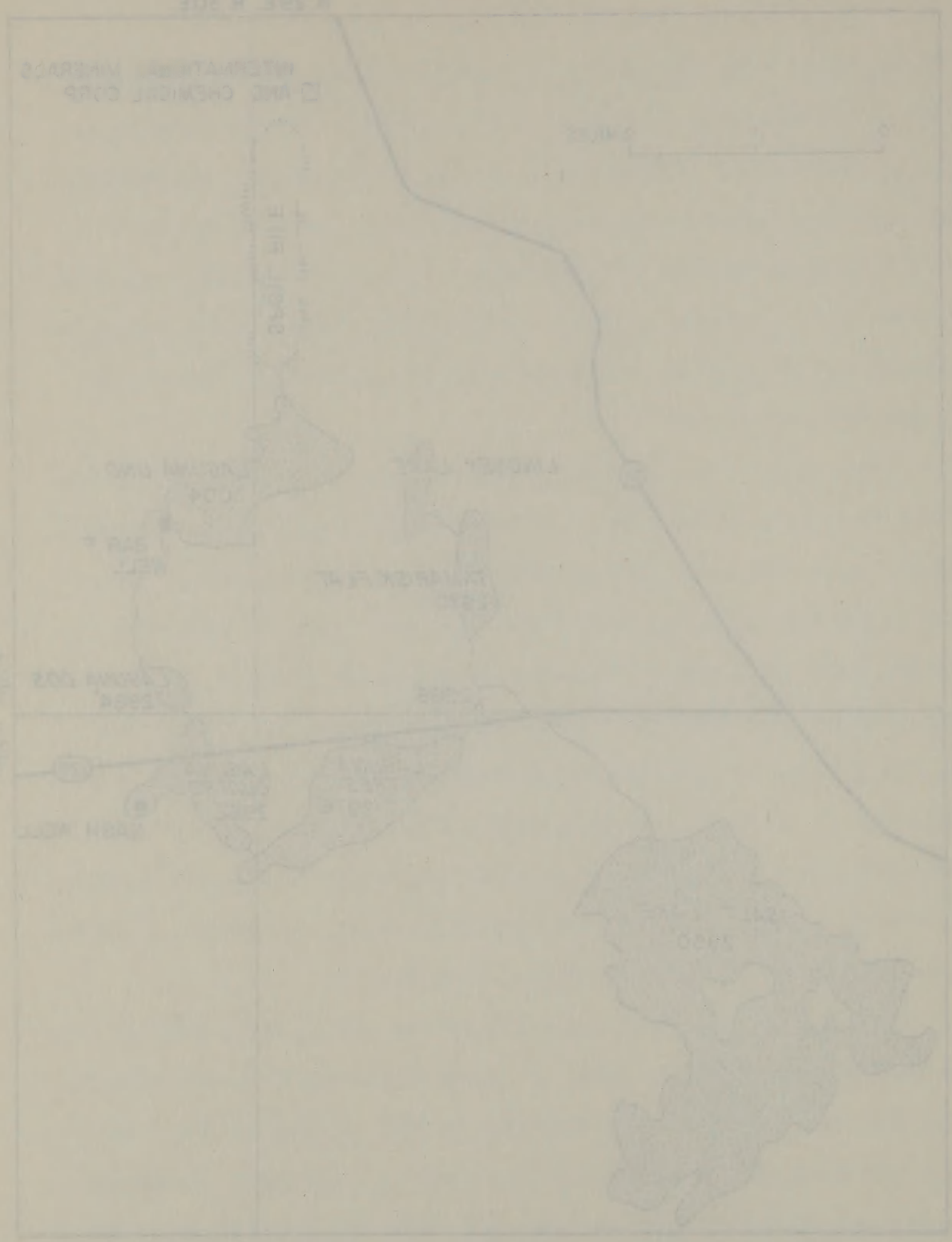


Figure 17. Distribution of lakes in the vicinity of IMC refinery and Salt Lake, with selected altitudes.



now (1979) at the land surface which establishes a rise of 134 feet in 31 years.

The IMC refinery has been in operation since 1947. During the early stages of operation, retention dams were used to pond the refinery waste; however, these have subsequently filled with sediment and the dams are now breached. Consequently the waste enters directly into Laguna Uno. Studies at the lake determined that the summer evaporation rate was 6.69 gpm per acre and the winter evaporation rate was 0.369 gpm per acre. Inasmuch as the area of Laguna Uno is 710 acres, the summer loss would be about 4,750 gpm and the winter loss would be about 260 gpm. Therefore it is likely that virtually all of the refinery inflow during the summer is lost by evaporation from the lake; however, during the winter months the evaporation is only about 10 percent of the inflow rate. This surplus waste water then enters the lake chain which eventually enters Salt Lake.

The amount of water loss from Laguna Uno is difficult to determine. The size of the lake prevents the sediment-laden refinery discharge from spreading evenly across the lake. As a result, most of the sediment is deposited at the upper end of the lake, and the southeast end of Laguna Uno is characterized by relatively clear, sediment-free water. Thus, there is no sealing effect at the fringes of the lake. There is very little seasonal change in lake level. This indicates that as brine inflow exceeds evaporation during the cooler months of the year, leakage from the lake offsets the lake-level rise. Thus, leakage from Laguna Uno acts as a stabilizing effect on the seasonal fluctuations of the lake.

The test-drilling program has shown that there may be movement of water from Salt Lake to the Pecos River (fig. 16), and that water from Laguna Uno joins the north edge of Salt Lake through a chain of smaller lakes. However there is no way to estimate the amount of refinery waste, if any, that enters Salt Lake. It has been determined that the evaporation of water from Laguna Uno is more than double the refinery inflow rate during the summer. Also, during the same season, the evaporation rate from the surface of Salt Lake may be as much as 17,000 gpm. The other lakes in the chain, including Laguna Dos, Laguna Tres, and Laguna Quatro, would also be capable of evaporating large quantities of water. Undoubtedly the evaporation rate in the IMC area is sufficient to consume the total amount of refinery wastes that are released to Laguna Uno during the warmer months of the year. However this evaporation loss may be offset during the cooler months, as indicated by the rise in lake levels of Laguna Uno and Laguna Quatro since 1948 or earlier.

THE CHEMICAL QUALITY OF WATER

Analyses of 11 water samples, 9 from new BLM wells and 2 from existing wells, are included in the Appendix of this report. Brine was encountered in 4 wells (table 6). Dissolved solids ranged from 55,870 ppm (parts per million) to 283,490 ppm with chlorides ranging from 14,640 to 142,500 ppm respectively. Three of these brine wells were located south and west of Salt Lake between the lake and the Pecos River. Two wells yielded salt water from the Rustler Formation and the third tapped Quaternary sand and gravel. The fourth brine-producing well tested is located two miles east of Williams Sink (20.32.17.13) and has water containing dissolved solids of 172,828 ppm. This well taps fine-to medium-grained calcareous sand of Quaternary age. Evidence suggests that the spoil pile and disposal ponds of National Potash Company, located near the test well, are the source of the brine.

Moderately saline water having dissolved solids of 10,260 ppm, sulfate of 3,125 ppm and chloride of 305 ppm, was produced from a well a few miles southeast of PCA (20.30.15.31). Calcareous Quaternary sands, probably playa lake deposits, yielded water to the well. The well has the highest transmissivity value of all wells tested, 470 ft^2/day. It is located a few hundred yards west of a depression that contains perennial brine ponds.

The remaining saline water samples contained dissolved solids in the 3,000 to

Table 6. Water-quality samples and producing formations.

Well Location	Sample Date	Total Dissolved Solids (ppm)	Source Formation	Lithology
19.30.33.31	12-21-78	3,320	Rustler	silty shale
20.30.15.31	12-29-78	10,260	Quaternary alluvium	calcareous sand
20.30.23.11	12-30-78	4,016	Dewey Lake Redbeds	silty calcareous shale
20.32.17.13	12-22-78	172,828	Quaternary alluvium	calcareous sand
20.32.22.33	12-19-78	3,136	Triassic shale	shale
21.29.25.423a	01-12-79	3,836	Rustler	unknown
21.29.25.423b	01-12-79	4,400	Rustler	unknown
21.31. 3.22	01-07-79	424	Dewey Lake Redbeds	siltstone and sand
23.29.18.14	01-05-79	55,876	Quaternary alluvium	sand and gravel
23.29.20.33	01-18-79	153,404	Rustler	limestone
23.29.28.41	12-18-78	283,492	Rustler	gypsum

4,000 ppm range. Chlorides were less than 300 ppm, and sulfates ranged from 550 ppm to 4,300 ppm. Fresh water was produced by a well tapping Triassic siltstone and sand northeast of the Kerr-McGee refinery (21.31.3.222). The dissolved solids were 424 ppm with chlorides of 18 ppm and sulfate of 20 ppm.

Locally, ground-water quality has been affected by potash-refinery waste disposal. Comparison of pre-potash mining ground-water levels and water-quality data with present data suggest that in somes cases, local ground-water levels have risen, and ground-water quality has deteriorated.

Data collected in 1948 (Hendrickson and Jones, 1952, table 1 and 3) show that a windmill in Williams Sink, about a mile west of National Potash (20.31.13.440), had a depth-to-water of 45 feet, and total dissolved solids of 7,080 ppm. The aquifer was reported as Triassic redbeds, and water quality was poor but suitable for stock. However at present, the windmill is abandoned and occupies the center of a brine lake created by the discharge of refinery wastes by National Potash into Williams Sink. The Quaternary sand and silt, which overlie the Triassic shale at this point, are saturated to ground level with brine.

A well (20.32.17.13) recently tested by Geohydrology Associates is about two miles east of Williams Sink, one and one-half miles west of Laguna Plata, and about one-half mile from the spoil pile of National Potash. Both Williams Sink and Laguna Plata receive refinery waste discharge from National Potash. When drilled, 42 feet of sand were penetrated before encountering the Triassic shales. Data from Williams Sink suggest

that in 1948, nine years prior to the beginning of refining operations by National Potash in 1957, the Quaternary sands were dry. Now, the depth-to-water is 9.6 feet (measured 12/19/78), and 32 feet of sand is saturated with brine.

Testing showed that the transmissivity of the sand was 350 ft^2/day. Other testing by Geohydrology Associates, Inc., has determined that the transmissivity of the Triassic shales which underlie the sand is about 10 ft^2/day. Brine infiltrating from the spoil pile and disposal ponds is spreading out across the buried surface of the Triassic shales and saturating the relatively thin overlying Quaternary sand deposits. The presence of brine at the test well indicates that movement of brine since 1957 from the National Potash spoil pile, which is the closest source of contamination, has been over 2,600 feet. This represents a minimum ground-water flow rate of 118 ft/year. Evidently a ground-water mound has formed, which has increased the ground-water gradient locally; thus increasing the rate of ground-water movement. The underlying Triassic shale has restricted downward movement and the lateral movement has increased.

In addition to the increase in ground-water mineralization that has occurred in the Williams Sink area, the water quality also has deteriorated south of IMC in Nash Draw. Hendrickson and Jones (1952) presented water analyses from wells in use in the late 1940's. Since this was not long after the start of potash mining and refining in the area, these analyses probably represent the natural, pre-development chemical quality of ground water in the area.

Samples collected from the J Bar F well (22.30.30.240) contained 3,290 ppm dissolved solids when sampled on April 30, 1950. The Nash well (23.30.6.420) was not sampled; however, it was in use as a stock well at that time. Both of these wells have subsequently been abandoned because of rising lake levels (fig. 17). The brine concentrations are considerably greater than during the Hendrickson and Jones study. Therefore, it is likely that the increase in mineralization is due primarily to the effects of refinery operations in the area.

Although the deterioration in water quality probably has resulted from brine discharge by the refineries, there is no evidence to indicate that potable water supplies have been affected. According to Hendrickson and Jones (1952, table 3), virtually all of the samples collected in Clayton Basin and Nash Draw exceeded the Public Health Service drinking water standards. Wells at the Wood Ranch (20.30.20.100) contained 3,050 ppm dissolved solids on May 1, 1950, whereas the Public Health Service recommended maximum is 1,000 ppm dissolved solids. A ranch well (20.30.33.440) located about two miles south of the Wood Ranch contained 3,860 ppm dissolved solids. The Crawford Ranch well (22.30.10.310) contained 2,280 ppm dissolved solids when sampled on April 30, 1950. Current analysis of samples from these wells are unavailable.

All of the other wells in Nash Draw and Clayton Basin also contained water that exceeded the Public Health Service standards. From this it may be concluded that refining operations have resulted in an increase in ground-water mineralization; however, the chemical quality of the ground water exceeded Public Health Service standards prior to the beginning of the potash activity in the area.

REFINERY SITING RECOMMENDATIONS

Although most of the vegetation in the potash-mining area is salt tolerant, the refinery waste products are saturated brines with total dissolved solids exceeding 300,000 ppm. Therefore, it is advantageous to contain the waste products whenever possible. Also, most of the ground water in Clayton Basin and Nash Draw has a mineral content of 2,000 ppm dissolved solids or more. Although this is not potable, additional deterioration should be avoided. Therefore, on the basis of data collected during the studies in the potash area by Geohydrology Associates, Inc., specific recommendations can be made to guard against additional deterioration of the hydrologic system in the area.

1. Refineries should be required to use retention structures which will prevent the waste products from coming into direct contact with the hydrologic system. Dumping of waste into unconfined arroyos should be prohibited.

The evaporation studies have shown that summer evaporation rates from disposal ponds may range from 6.60 to 8.91 gpm per acre of surface area; the average is 7.8 gpm per acre. Winter evaporation rates ranged from 0.308 to 0.369 gpm per acre and averaged 0.338 gpm per acre of surface area. In order to evaporate as much of the discharge as possible during the summer months, a refinery would need approximately 130 acres of disposal pond surface for each 1,000 gallons per minute of refinery discharge.

2. Brine-disposal ponds should be contructed in those areas where minimum ground-water migration can be expected and where non-potable ground water is known to be present.

Transmissivity, porosity, and ground-water gradient in the units underlying a potential site determine the rate of ground-water movement that can be expected. Ground-water quality at a potential site is closely related to the lithology of the water-bearing zones. Gyspum and shale characteristically contain water of fair to poor quality. Better water can be expected from sandstone, limestone, and dolomite. Rates of ground-water movement and water quality are discussed in detail in a previous section of this report.

The preferred sites for disposal ponds are in the deeper parts of Clayton Basin, the Maroon Cliffs area, and the shale deposits east of Livingston and Nimenim Ridges (fig. 18).

The Dewey Lake Redbeds and the Triassic shales offer the greatest potential for retention of fluids. The coefficients of transmissivity measured in wells tapping these deposits indicate that the flow rates through the depoists are generally less than 17 feet per year. Assuming a plant life of 40 years, the waste products would not migrate more than about 680 feet from the disposal ponds.

Clayton Basin is a closed ground-water basin of interior drainage. The lowest point in the basin is Clayton Lake, a natural ground-water discharge point. Refinery waste emptied into this lake, or other sites in the basin, would be adequately contained.

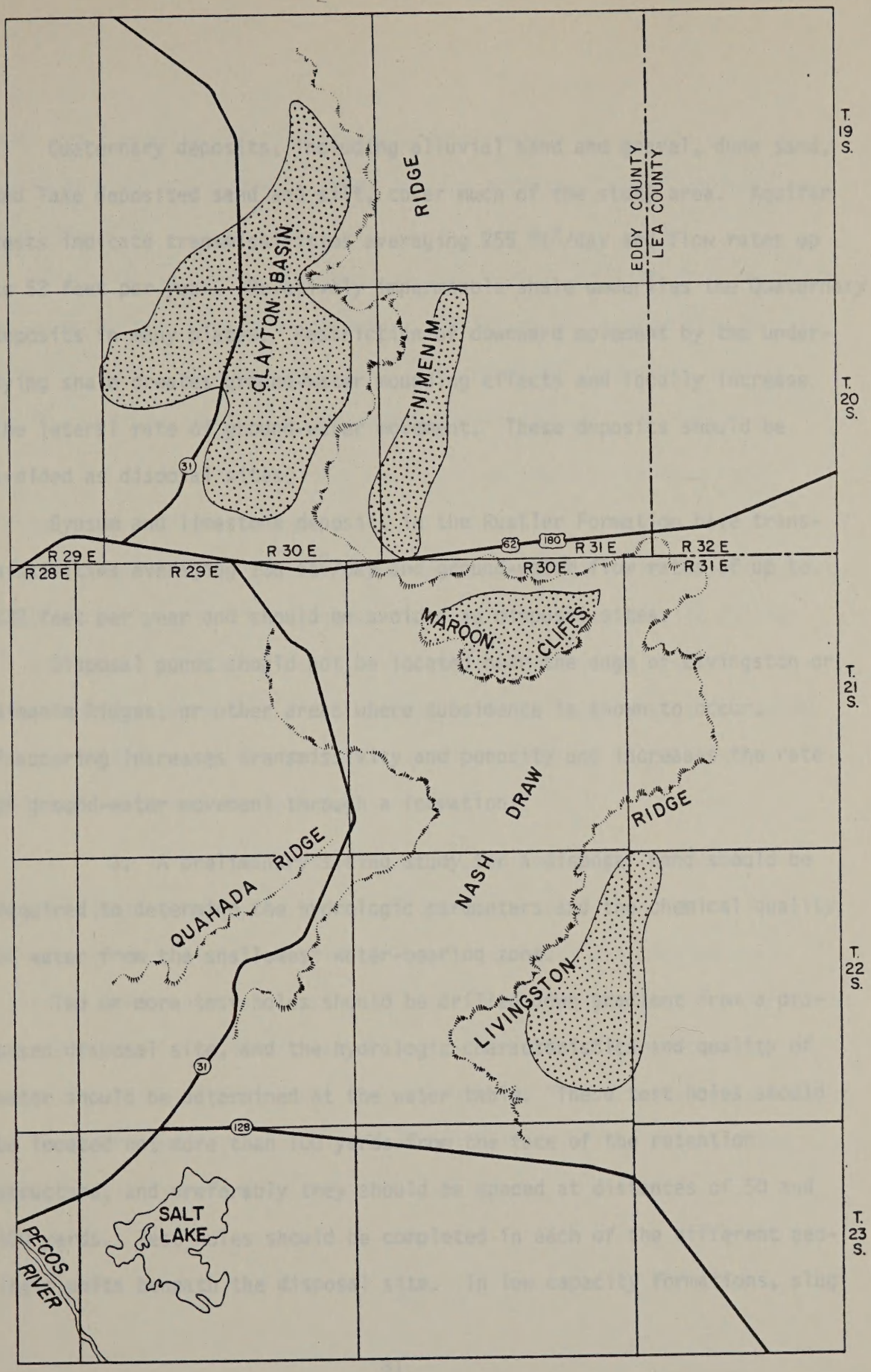
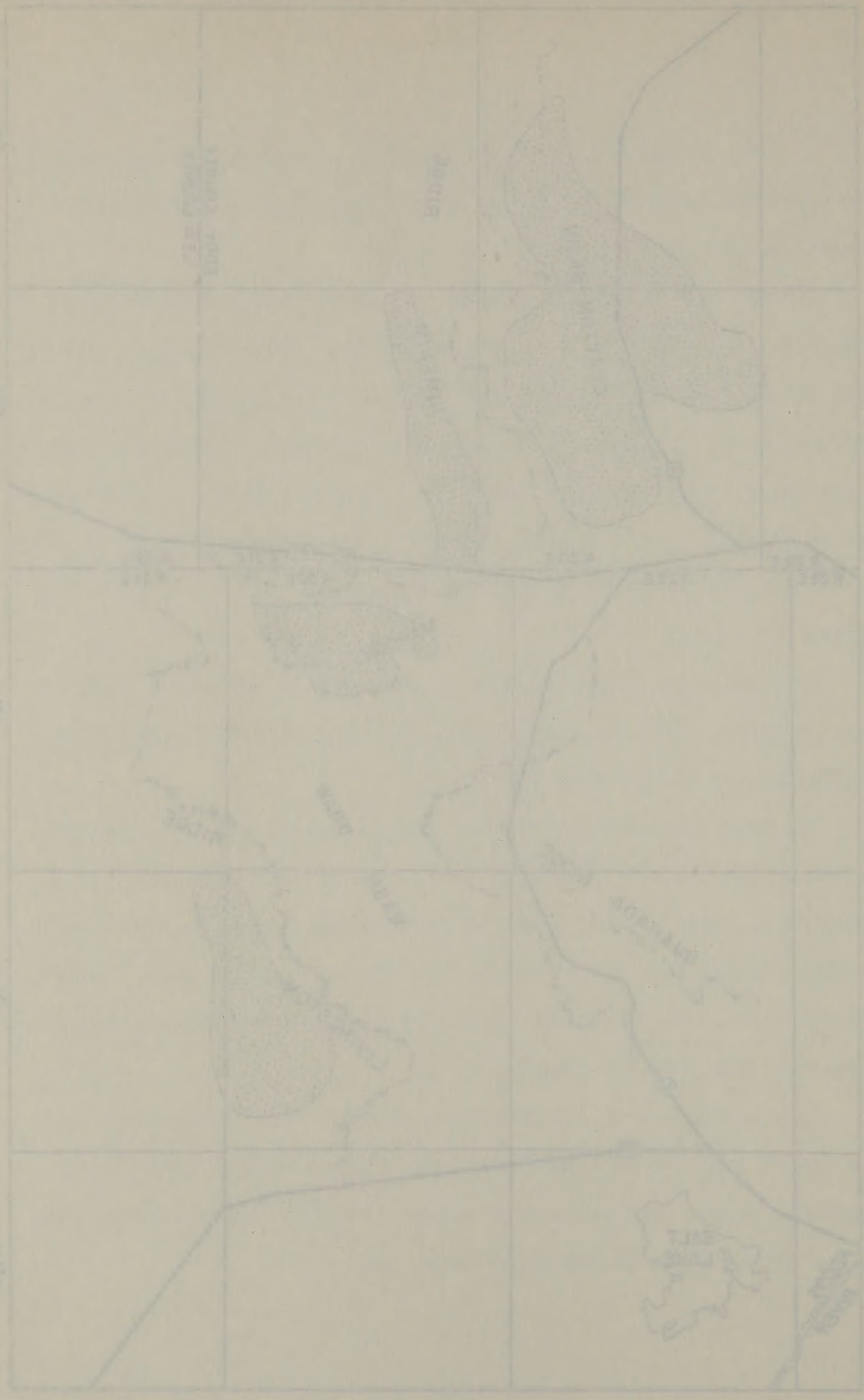


Figure 18. Preferred locations (stippled areas) for potash refineries.



Quaternary deposits, including alluvial sand and gravel, dune sand, and lake deposited sand and silt, cover much of the study area. Aquifer tests indicate transmissivities averaging 255 ft^2/day and flow rates up to 52 feet per year. Relatively impermeable shale underlies the Quaternary deposits in many places. Restriction of downward movement by the underlying shale creates ground-water mounding effects and locally increase the lateral rate of ground-water movement. These deposits should be avoided as disposal sites.

Gypsum and limestone deposits in the Rustler Formation have transmissivities averaging 136 ft^2/day and ground-water flow rates of up to 232 feet per year and should be avoided as disposal sites.

Disposal ponds should not be located near the edge of Livingston or Nimenim Ridges, or other areas where subsidence is known to occur. Fracturing increases transmissivity and porosity and increases the rate of ground-water movement through a formation.

3. A preliminary siting study for a disposal pond should be required to determine the hydrologic parameters and the chemical quality of water from the shallowest water-bearing zone.

Two or more test holes should be drilled down gradient from a proposed disposal site, and the hydrologic characteristics and quality of water should be determined at the water table. These test holes should be located not more than 100 yards from the face of the retention structure, and preferably they should be spaced at distances of 50 and 100 yards. Test holes should be completed in each of the different geologic units beneath the disposal site. In low capacity formations, slug

tests would provide the most accurate measurements of coefficients of transmissivity and storage. Water quality samples could be bailed from each test hole.

The holes should be completed as observation wells so that periodic measurements can be made to determine the amount of leakage from the disposal ponds. Water samples should be collected regularly, perhaps yearly, in order to monitor the water-quality changes, if any.

4. All future refineries should be required to meter the discharge of refinery wastes.

Although refinery discharge may contain as much as 30 percent solids, a record of the total discharge would provide an approximation of the maximum amount of liquid that is released to the disposal ponds. This information, together with the evaporation data, would enable the Bureau of Land Management to estimate the amount of refinery waste that is entering the hydrologic system.

5. Refineries should be encouraged to design plants that are capable of utilizing brine in the refining process.

Recent developments in refining technique have enabled two refineries (AMAX and Mississippi Chemical) to utilize the highly mineralized water produced by wells located in the potash area. This technique reduces the amount of water that must be imported from fresh-water aquifers, and then subsequently released as saturated brine. Thus it is a good water-conservation measure.

6. Drilling and testing as described in item 3 should be conducted at those refineries where the Bureau of Land Management has special concern about the rate and direction of brine seepage.

This would require that two or more shallow test holes be drilled and tested at selected sites bordering the disposal ponds. It has been shown that the PCA refinery discharge is evaporated on site, however seepage loses do occur at all of the other refineries. The IMC refinery presents a special set of problems which are discussed in item 8.

7. All existing refineries should be required to meter the discharge of refinery wastes. This would be a relatively simple and inexpensive modification, and it would provide the Bureau of Land Management with accurate measurements of the plant discharge.

8. Laguna Uno is a very poor evaporation pond owing to the amount of leakage from the lake. Therefore it would be advantageous for the International Mineral and Chemical Corporation to use more conventional evaporation ponds which would release less brine to the hydrologic environment.

CONCLUSIONS

The drilling and aquifer-testing program performed by Geohydrology Associates, Inc., for the BLM in the potash area, has provided information which gives a better understanding of the hydrologic system in the Nash Draw area and a clearer picture of the effect of potash mining on the hydrologic system.

1. Although the refining operations have increased the mineralization of ground water in the vicinity of the plants, earlier studies indicate that there was no potable water in these areas prior to the beginning of potash development.

2. Aquifer tests were performed on wells which penetrated the saturated zone to sufficient depth for testing. The wide range in transmissivity values (470 ft^2/day to 0.06 ft^2/day) reflect the variance in aquifer properties between different formation and aquifer types. Tests were made on Quaternary sands and gravel deposits (mean: 255 ft^2/day), Triassic shales and sandstone (mean: 9,8 ft^2/day), siltstone and shales of the Dewey Lake Redbeds (mean: 4.9 ft^2/day) and on gypsum, siltstone, and dolomites of the Rustler Formation (mean: 136 ft^2/day).

3. Flow rates for the 18 wells tested ranged from 0.02 ft/year to 232 ft/year. These flow rates were used to estimate total distance of brine movement in the disposal ponds of active potash operations, since the start of refining operations. With the exception of IMC, which discharges its waste into a natural brine lake, the greatest calculated total

movement of infiltrated brine was 6,267 feet from a pond constructed on top of the Rustler Formation by AMAX. Values for the other brine disposal ponds has had little effect on the regional water quality although local effects may be significant.

4. The evaporation and leakage studies of IMC's disposal pond, Laguna Uno, and of PCA's disposal pond have provided a better understanding of these specific sites, as well as giving insight into the hydrology of brine ponds.

Laguna Uno is a natural brine lake and receives the discharge of IMC. Study results indicated that Laguna Uno leaks at a rate of 100 gpm to 3,300 gpm and that leakage probably varies seasonally. During the winter, when evaporation is low, the lake contains a surplus of water, and the balance is maintained by an increase in leakage. During the summer, inflow into Laguna Uno is closely matched by evaporation, and leakage is decreased.

The PCA disposal pond was created by ponding of refinery discharge in a natural depression. Leakage was found to be about 500 gpm and is quite possibly much less. The lake level of PCA exhibits strong response to seasonal evaporation rate differences with the winter pond level in 1979 almost three feet higher than the 1978 summer level.

Evaporation rates determined at Laguna Uno and the PCA disposal pond were much greater in summer than in winter. Summer rates averaged 7.8 gpm per acre, while winter rates averaged 0.338 gpm per acre.

Spoil-pile loss during periods of high evaporation was found to be significant. At least 75 percent of the discharge of IMC onto the spoil

pile was lost to evaporation before it reached Laguna Uno during the periods of high evaporation. The winter study also showed a strong correlation between evaporation rate and spoil pile loss.

5. Results of the drilling program indicate that Salt Lake may discharge into the Pecos River via the ground water. However, because of the high natural salinity of Salt Lake and the high evaporation rate for Laguna Uno and the other lakes below IMC, it cannot be documented that refinery waste has an adverse effect on the Pecos River.

6. Analyses were run on 11 water samples. Aquifers sampled included: Quaternary sands, Triassic shales, siltstones, and sands; siltstone and shale of the Dewey Lake Redbeds; and gypsum, anhydrite, siltstone, and dolomite of the Rustler Formation. The effect of the regional geology on the water quality is pronounced.

Brine was encountered in four wells. Three wells were south of Salt Lake; one was near the National Potash refinery.

Moderately saline water, having dissolved solids of 10,260 ppm, was found in a well located near a perennial natural brine pond in Clayton Basin a few miles southeast of PCA.

The remaining samples contained dissolved solids in the 3,000 to 4,000 ppm range. These values are typical of water produced from gypsum and shale.

Ground-water quality has been affected locally by potash-refinery waste disposal. Ground-water-level data and water-quality data collected in 1948, when compared to recent data, show that ground-water levels near Williams Sink and Laguna Uno have risen significantly, and also

indicate a local deterioration of ground-water quality.

7. The attempt to correlate precipitation and ground-water levels showed that the shallow wells apparently display short-term highs in water levels in response to anomalously high precipitation. The water levels in general fluctuate seasonally, but it is difficult to determine whether the fluctuations are in response to precipitation or evapotranspiration. Making firm judgements would require a substantially longer time period for which water-level and precipitation data are available.

8. The preferred refinery sites are in the deeper parts of Clayton Basin, on the Maroon Cliffs in northern Nash Draw, and on the shale deposits east of Livingston and Nimenim Ridges. Disposal ponds constructed at these sites should have a minimum surface area of 130 acres per 1,000 gallons per minute of refinery discharge. Prior to construction of disposal sites, the chemical quality of the ground water, and the hydrologic properties of the shallowest aquifer, should be determined and documented. Observation wells should be maintained for subsequent monitoring.

9. Additional studies of the potash area may not be warranted. Although aquifer tests have not been conducted in Nash Draw, the geologic units have been previously mapped. Tests in similar aquifers elsewhere in the project area have shown that the hydrologic properties generally are very low and the rate of ground-water flow is less than about 10 feet per year. Much of Nash Draw is underlain by the Tamarisk Member of the Rustler Formation which would not be acceptable for disposal sites. Thus

additional drilling and testing of this geologic unit is not justified.

Owing to the average lifespan of a potash refinery, and the slow rate of ground-water movement away from the disposal site, tracer studies probably would not be practical. The brine contaminants apparently have not migrated a sufficient distance to justify tracer studies.

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A P P E N D I X

DRAWDOWN AND RECOVERY CURVES

SLUG-TEST DATA

LITHOLOGIC LOGS

GAMMA LOGS

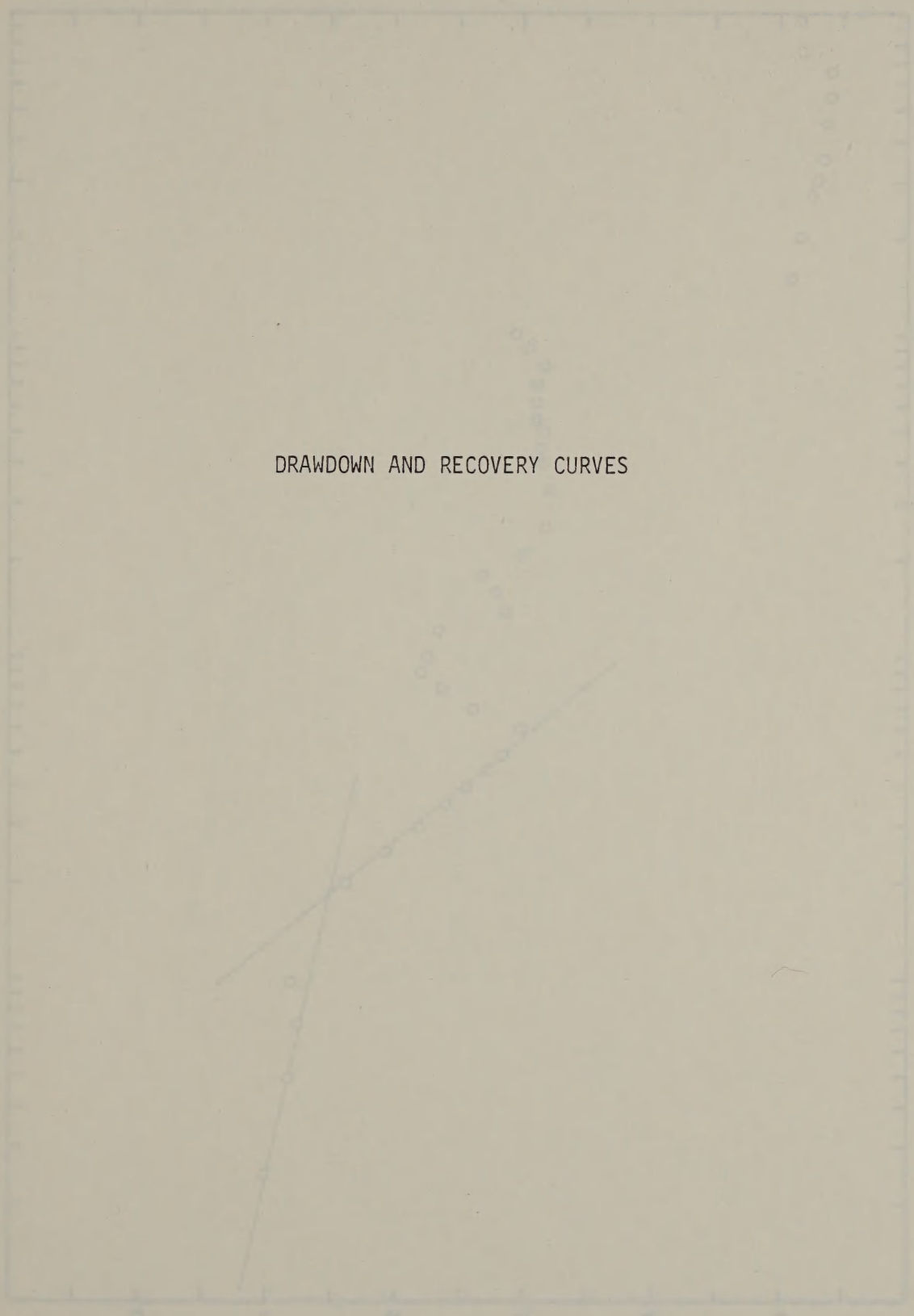
CHEMICAL WATER ANALYSES

RECORDS OF WELLS AND TEST HOLES IN PROJECT AREA

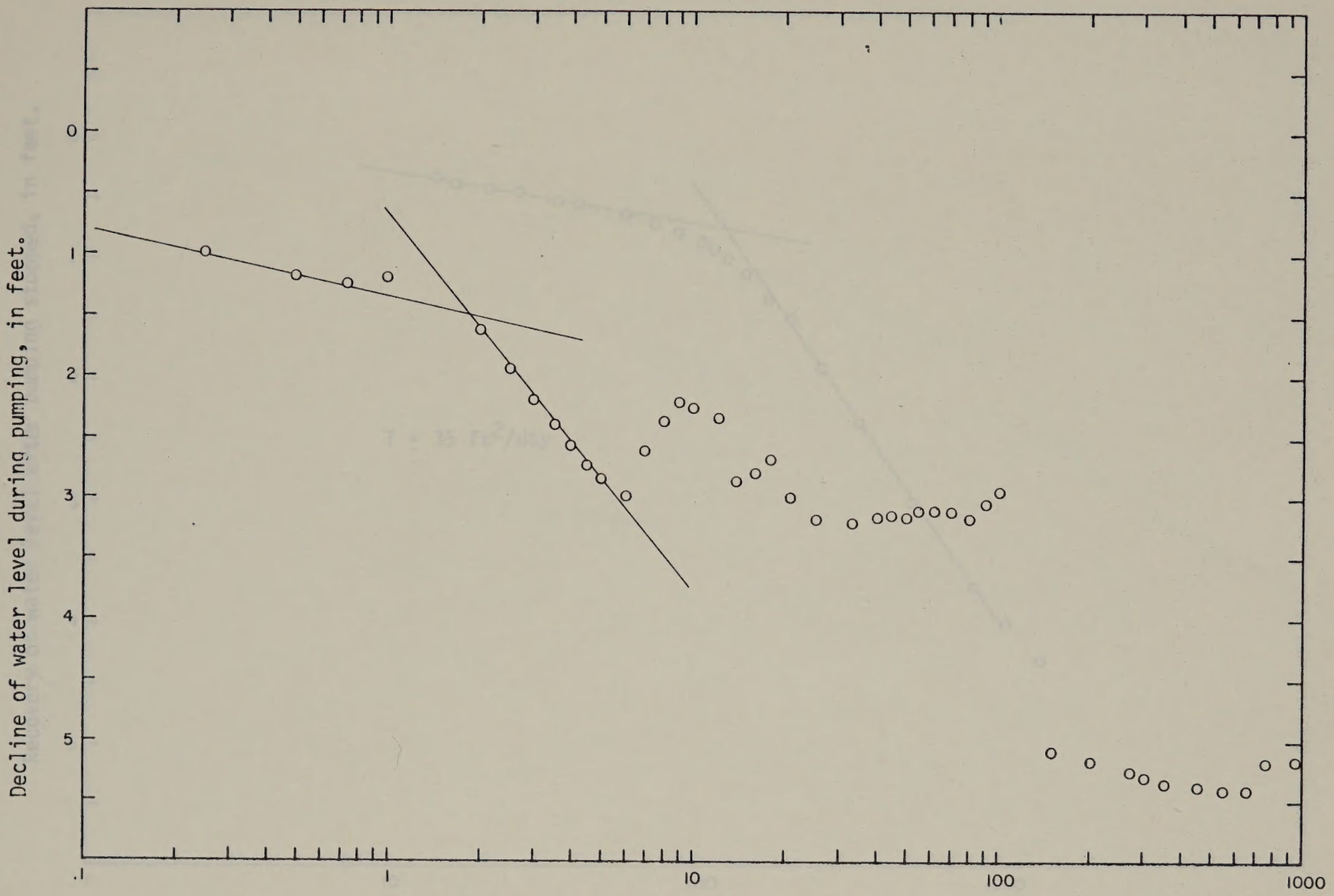
WATER-LEVEL RECORDS OF SELECTED OBSERVATION WELLS

RAIN GAGE NETWORK RECORDS

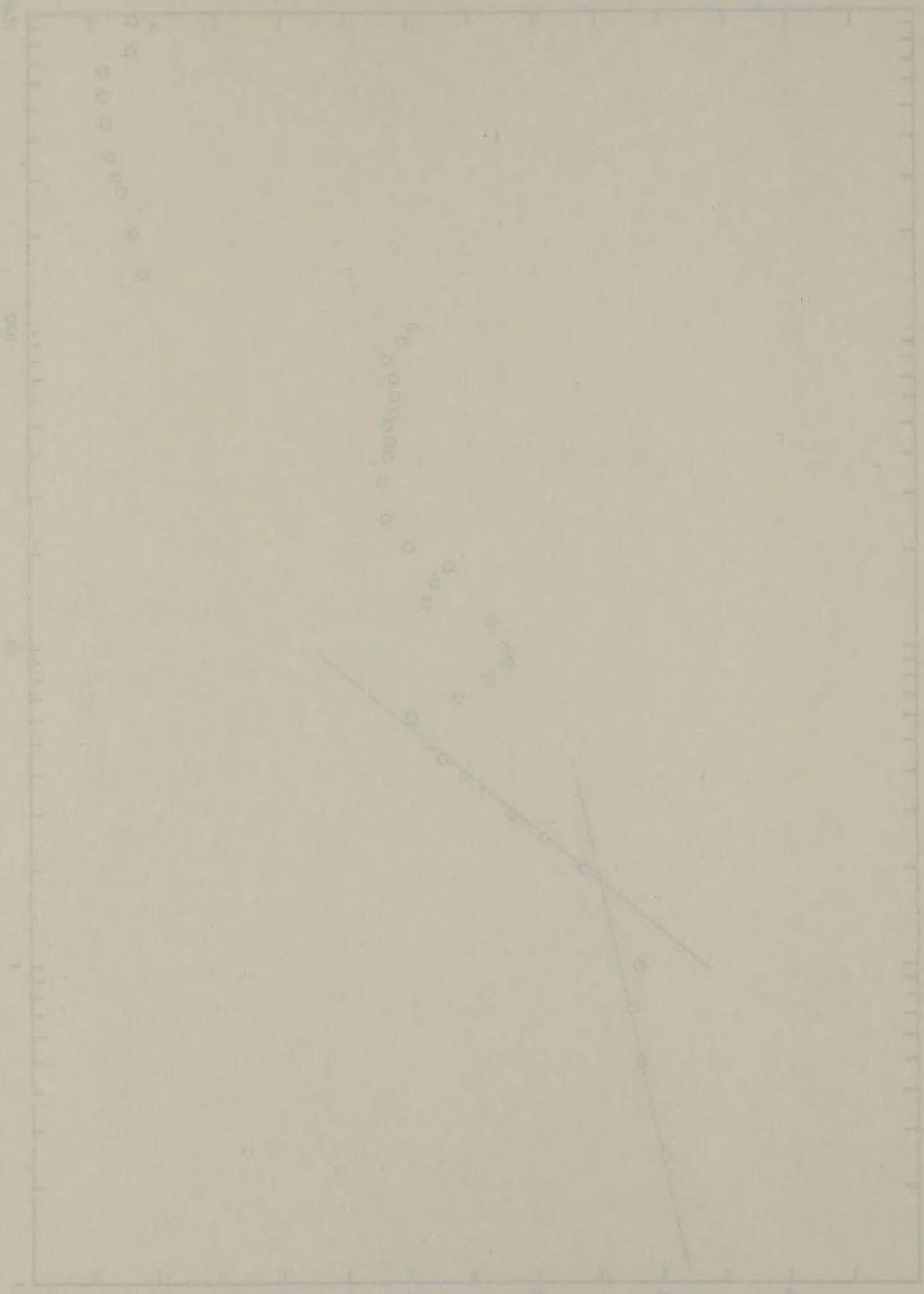
DRAWDOWN AND RECOVERY CURVES



Drawdown and recovery curves



Plot of drawdown data for well at 19.30.33.31.



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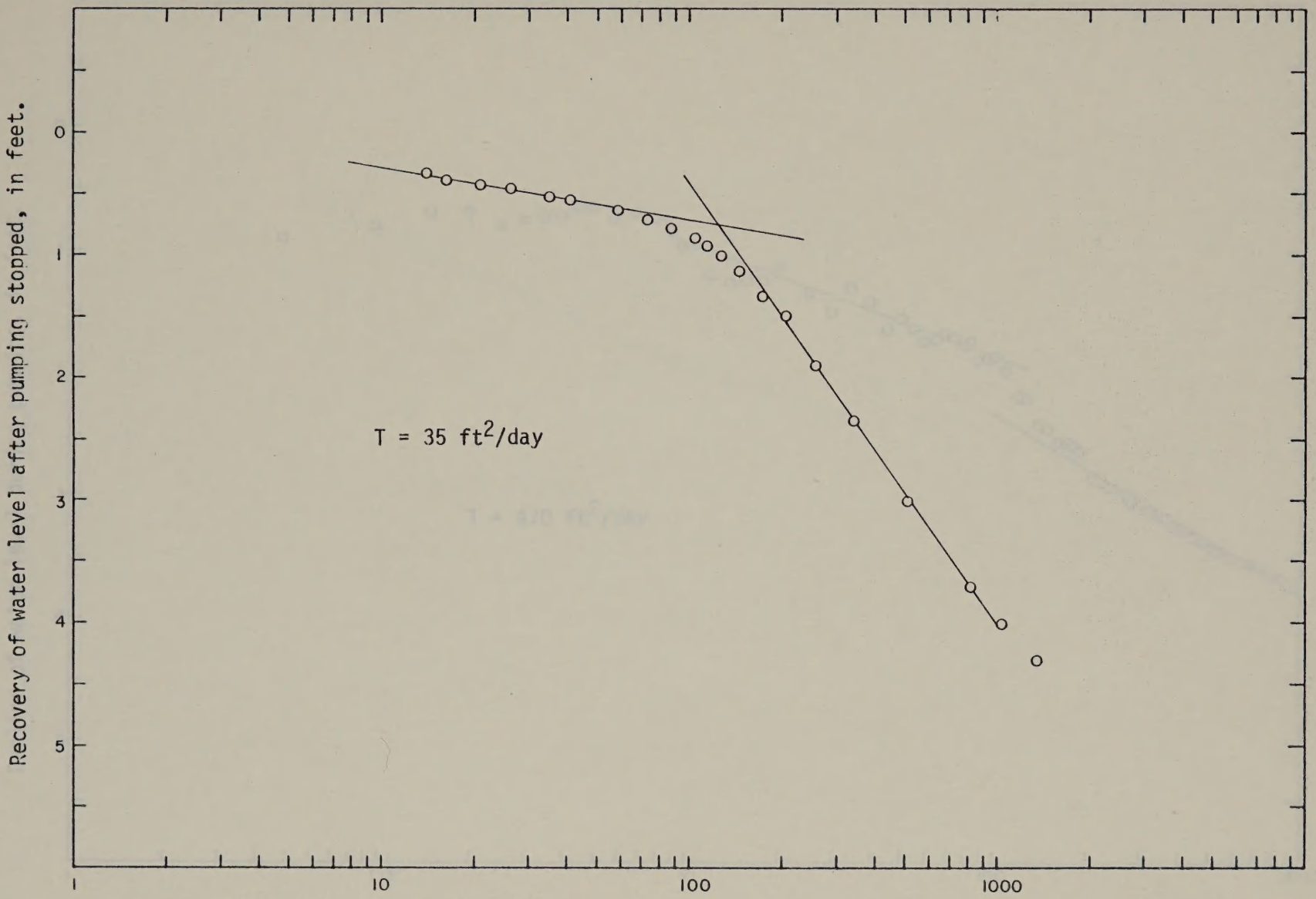

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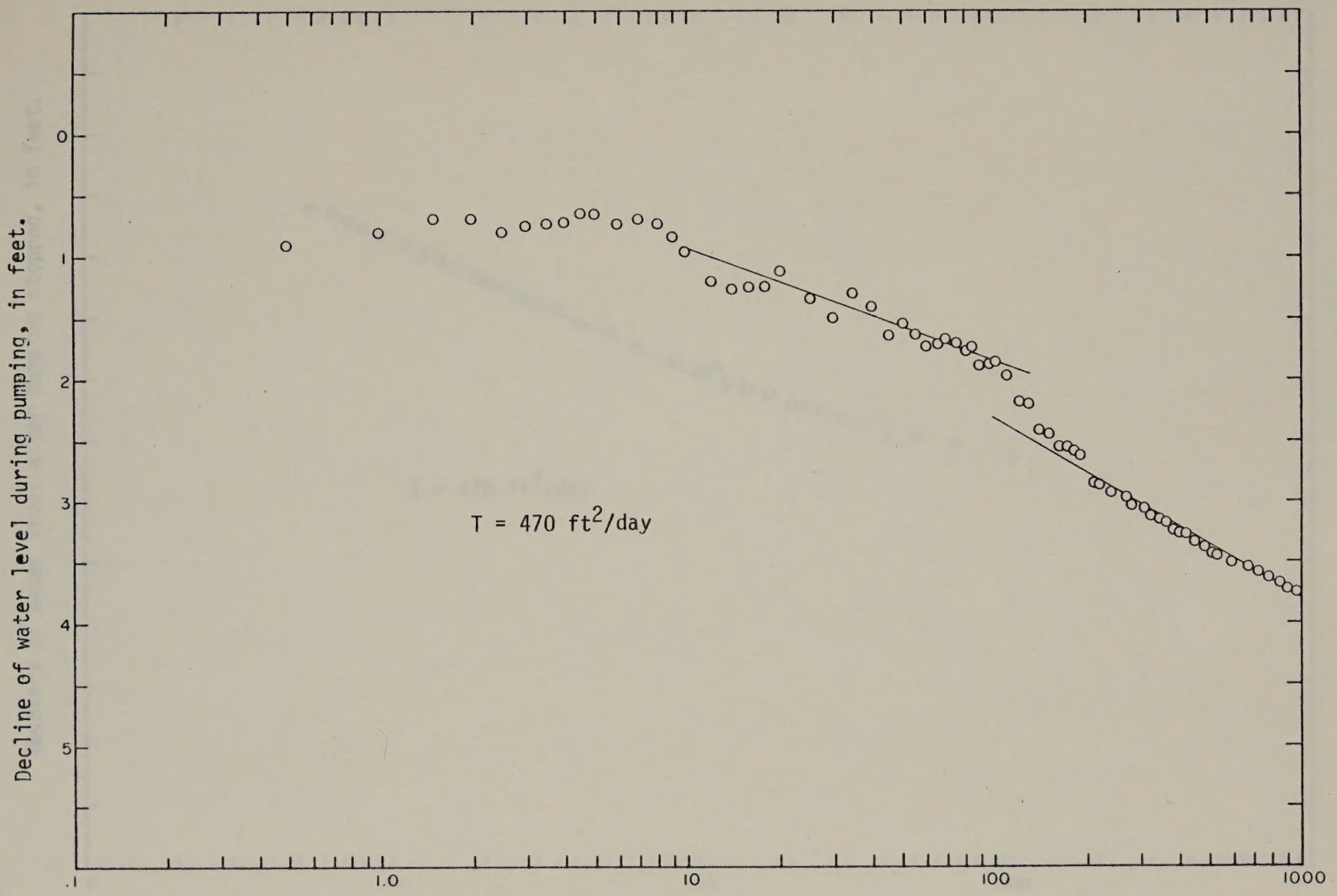

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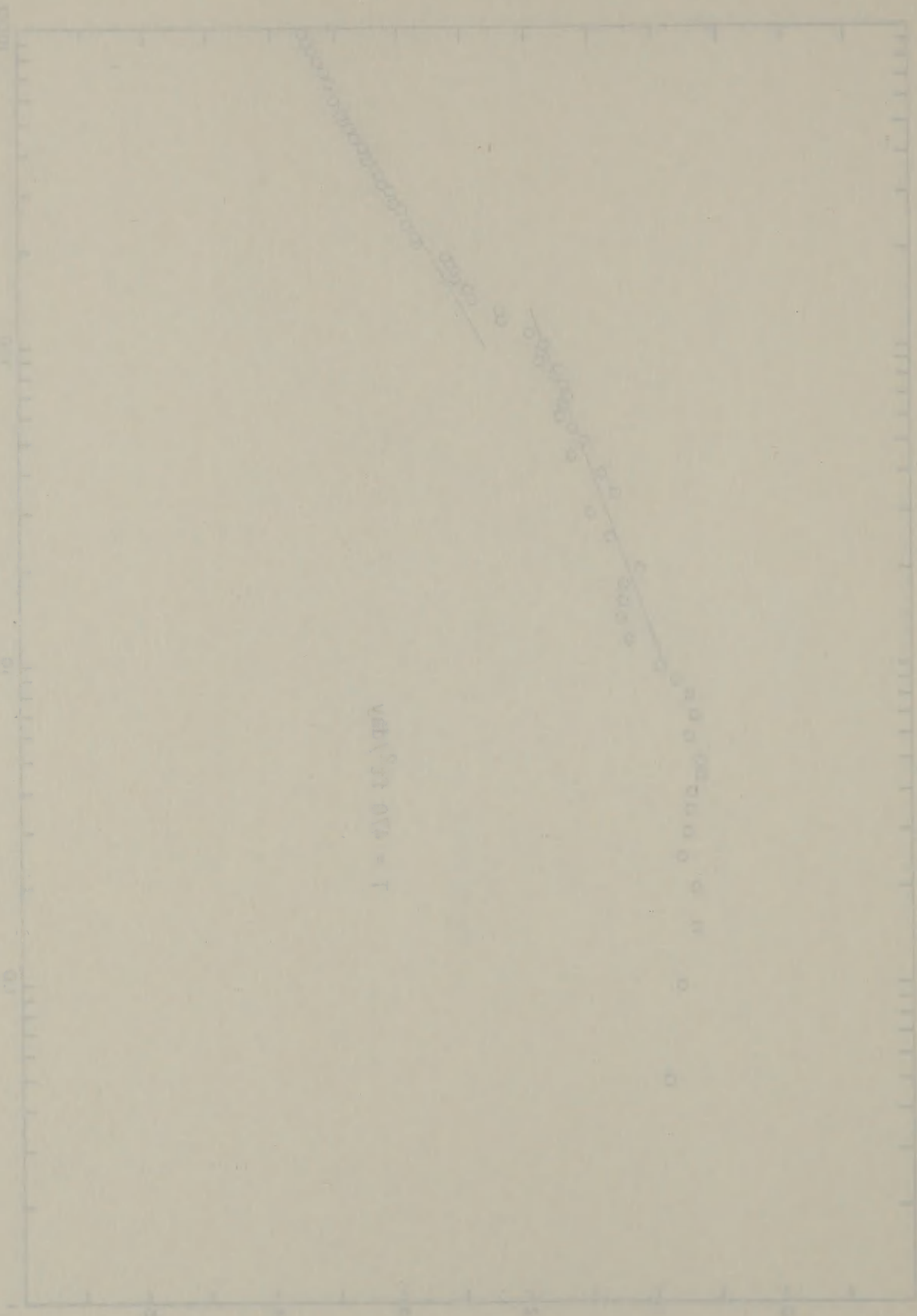

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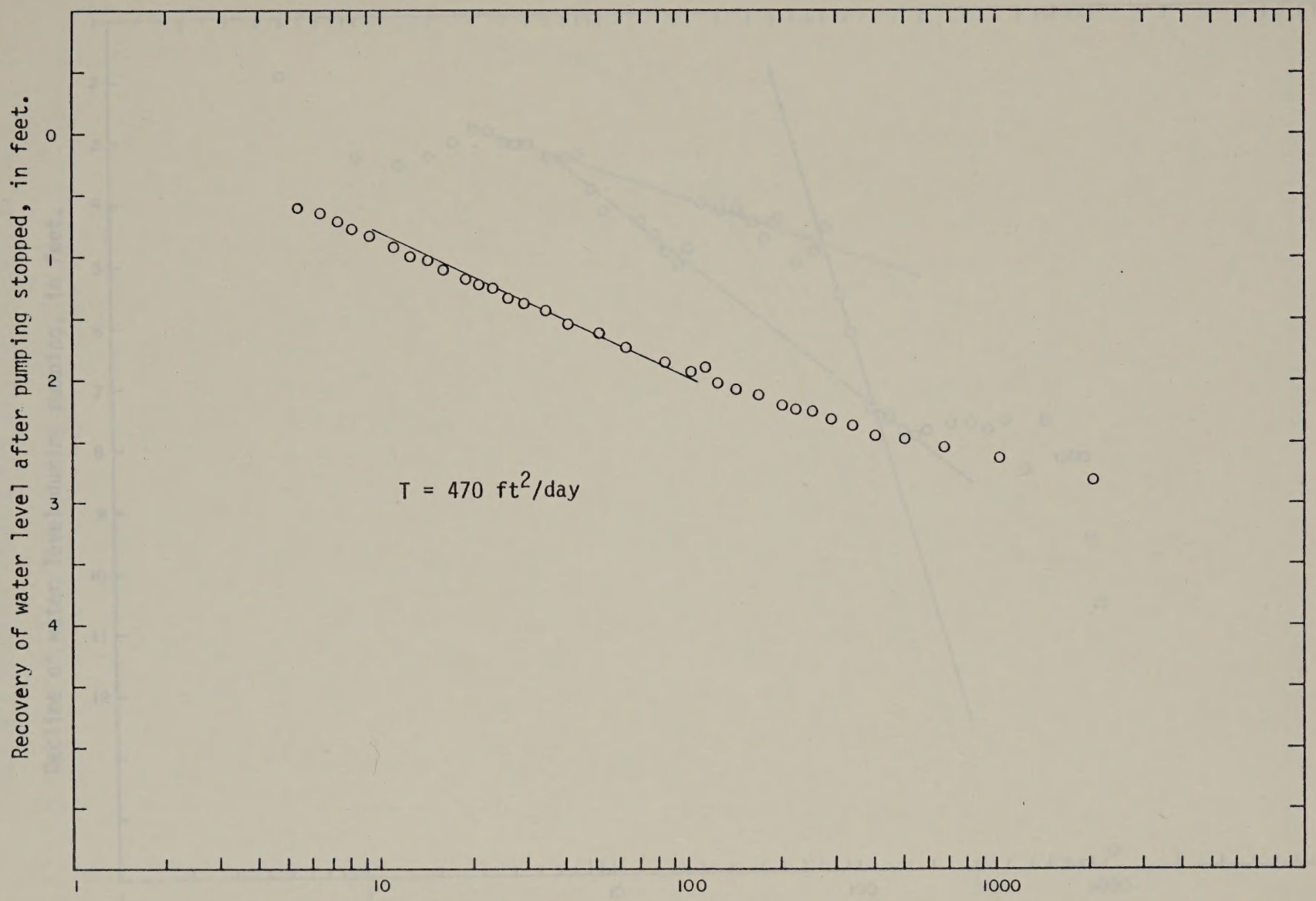

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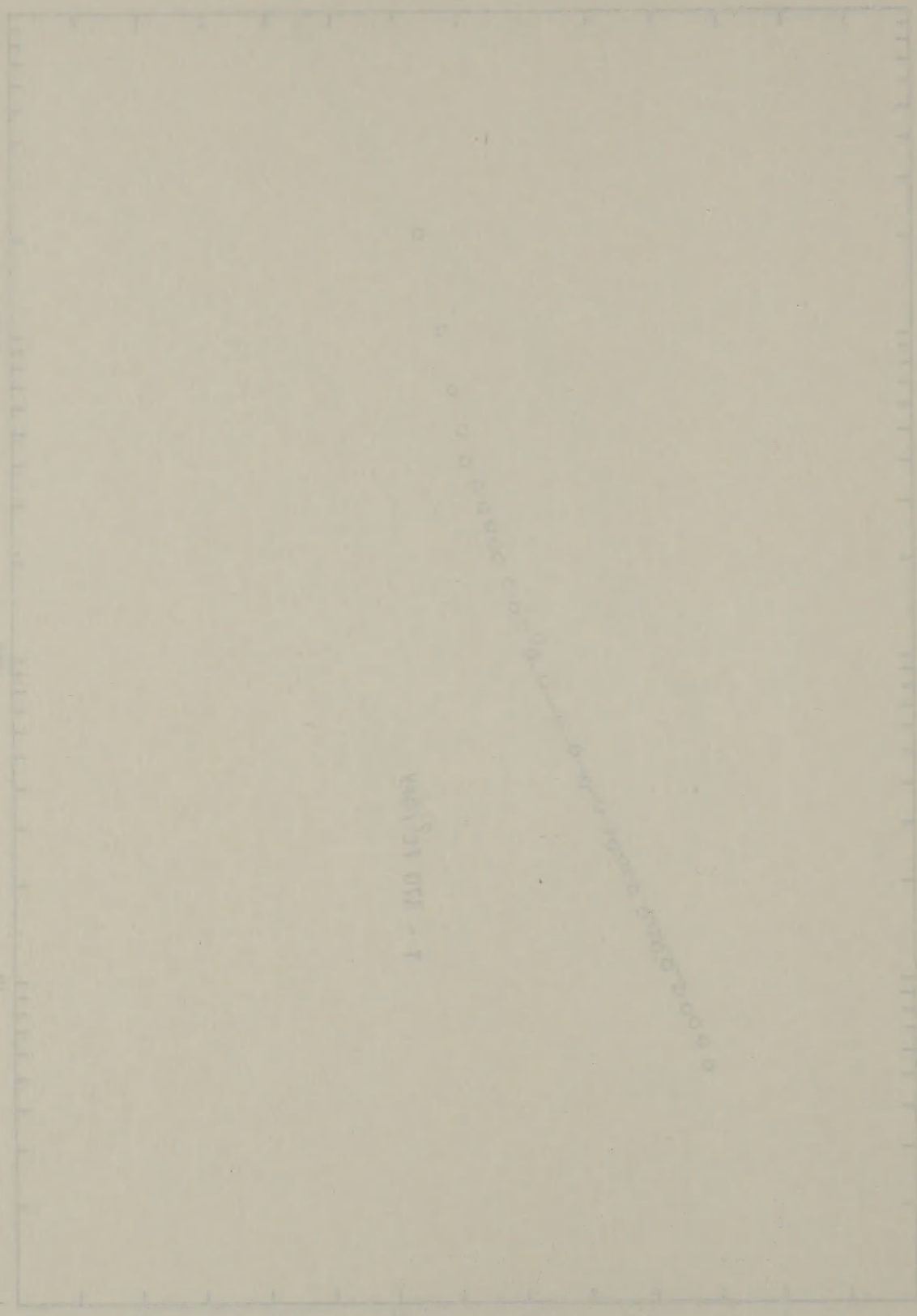

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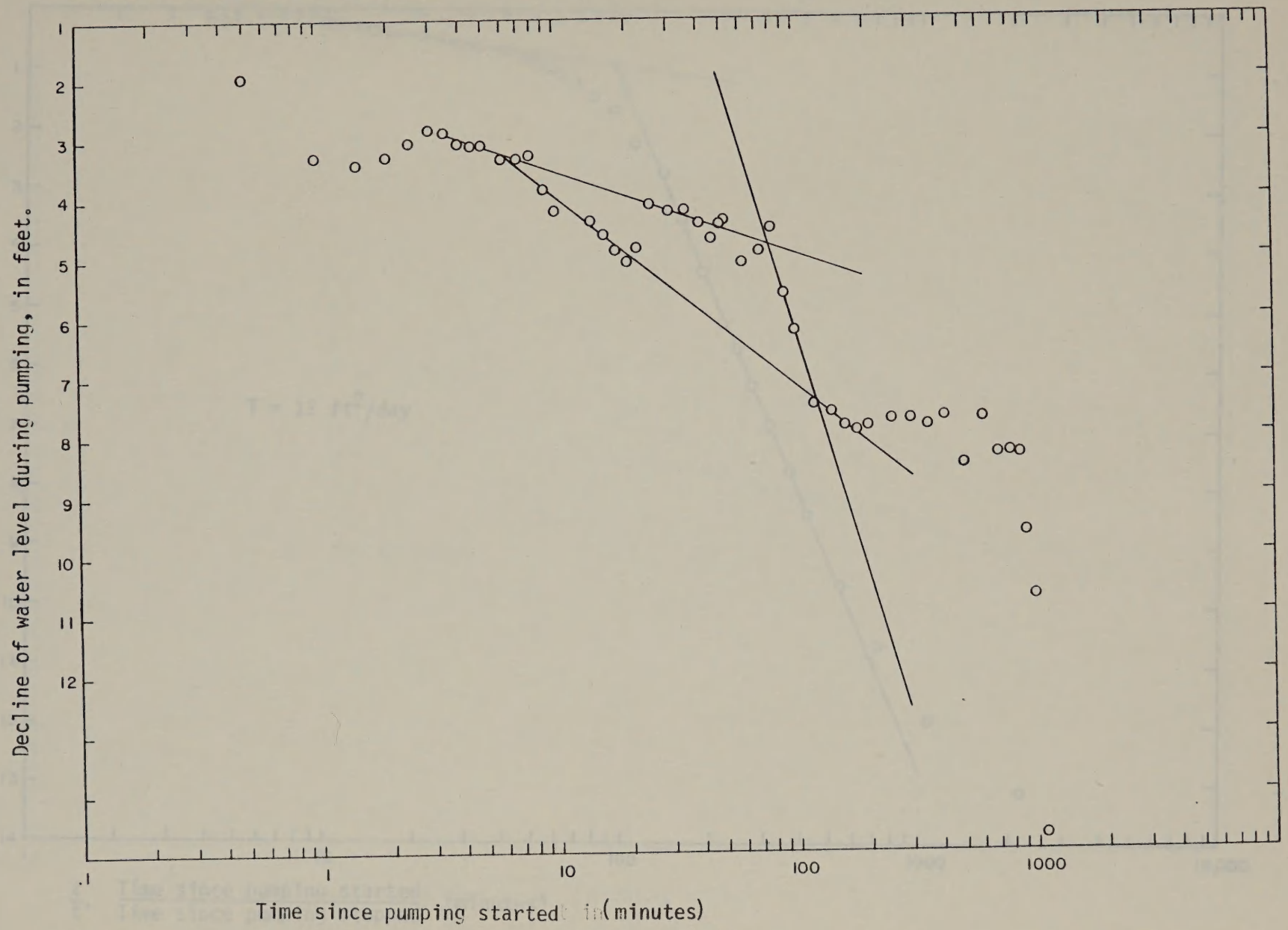

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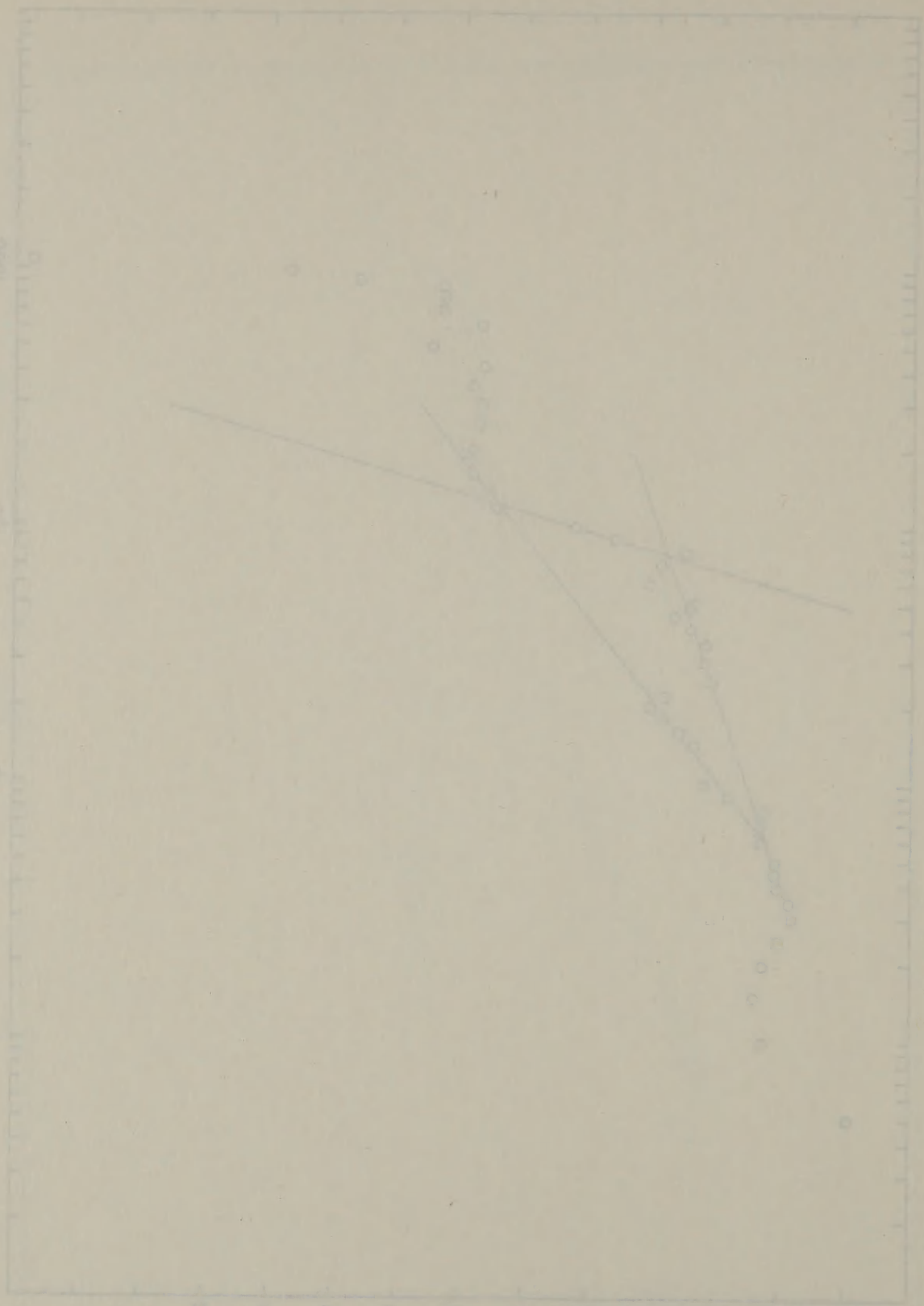

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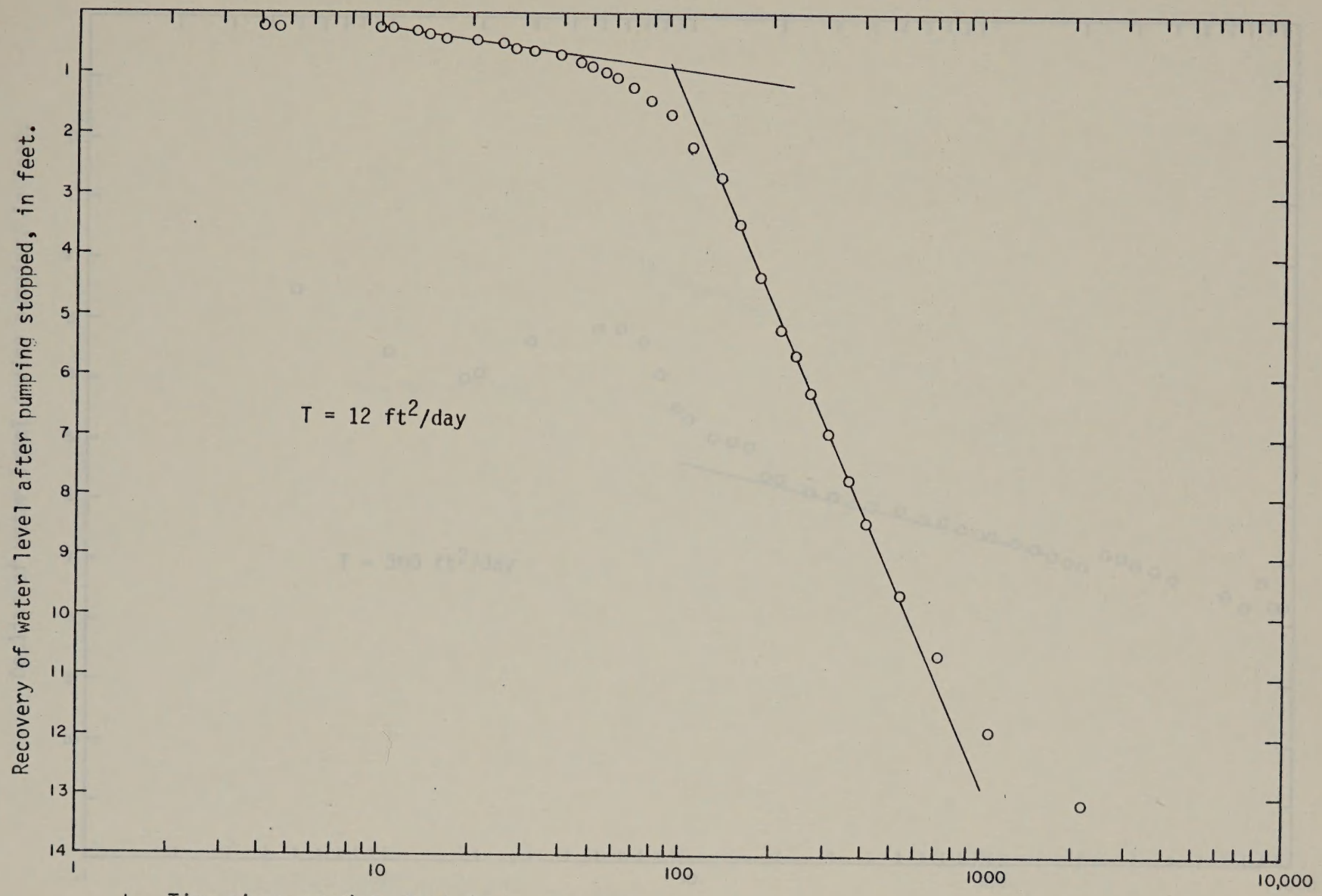

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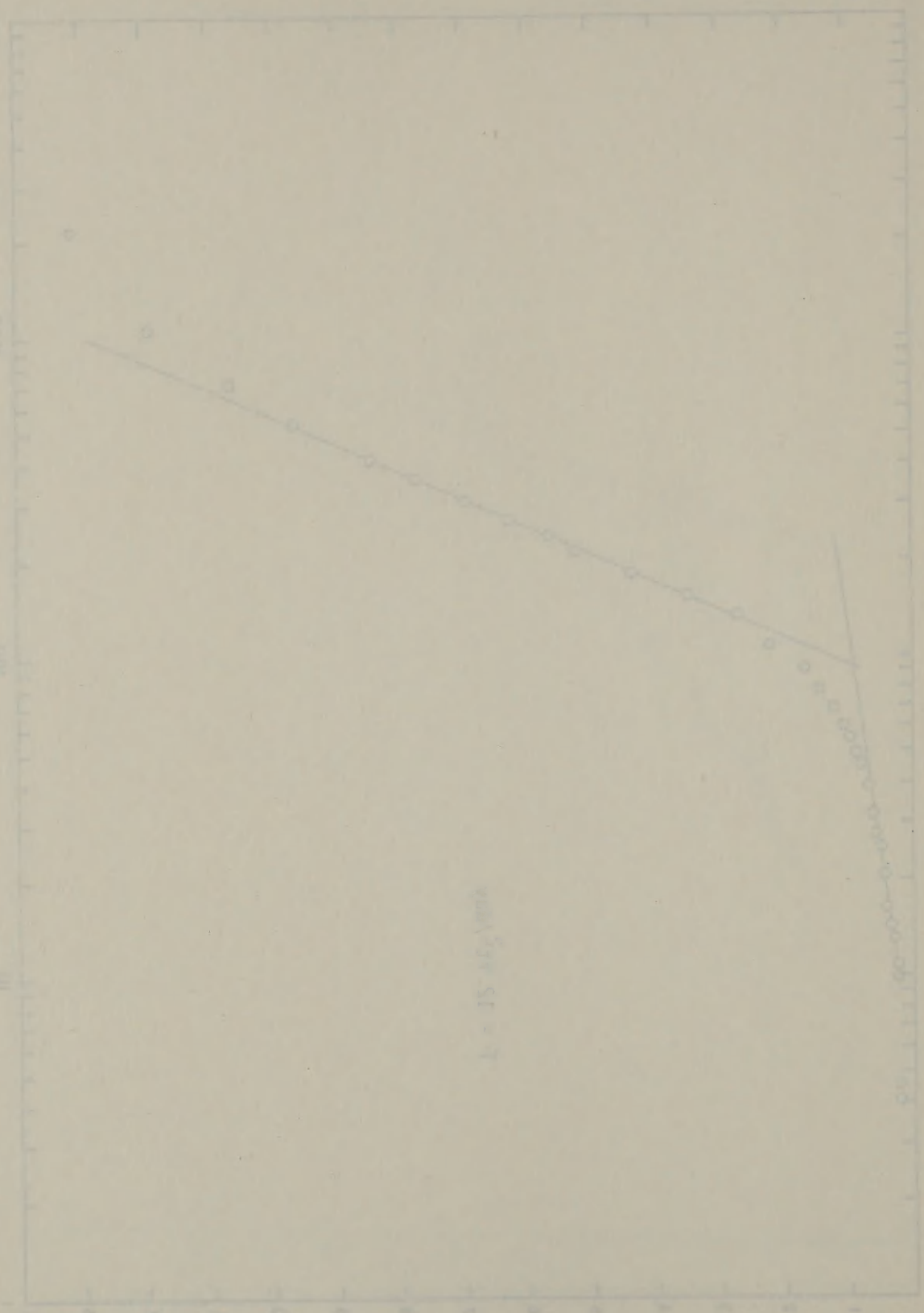
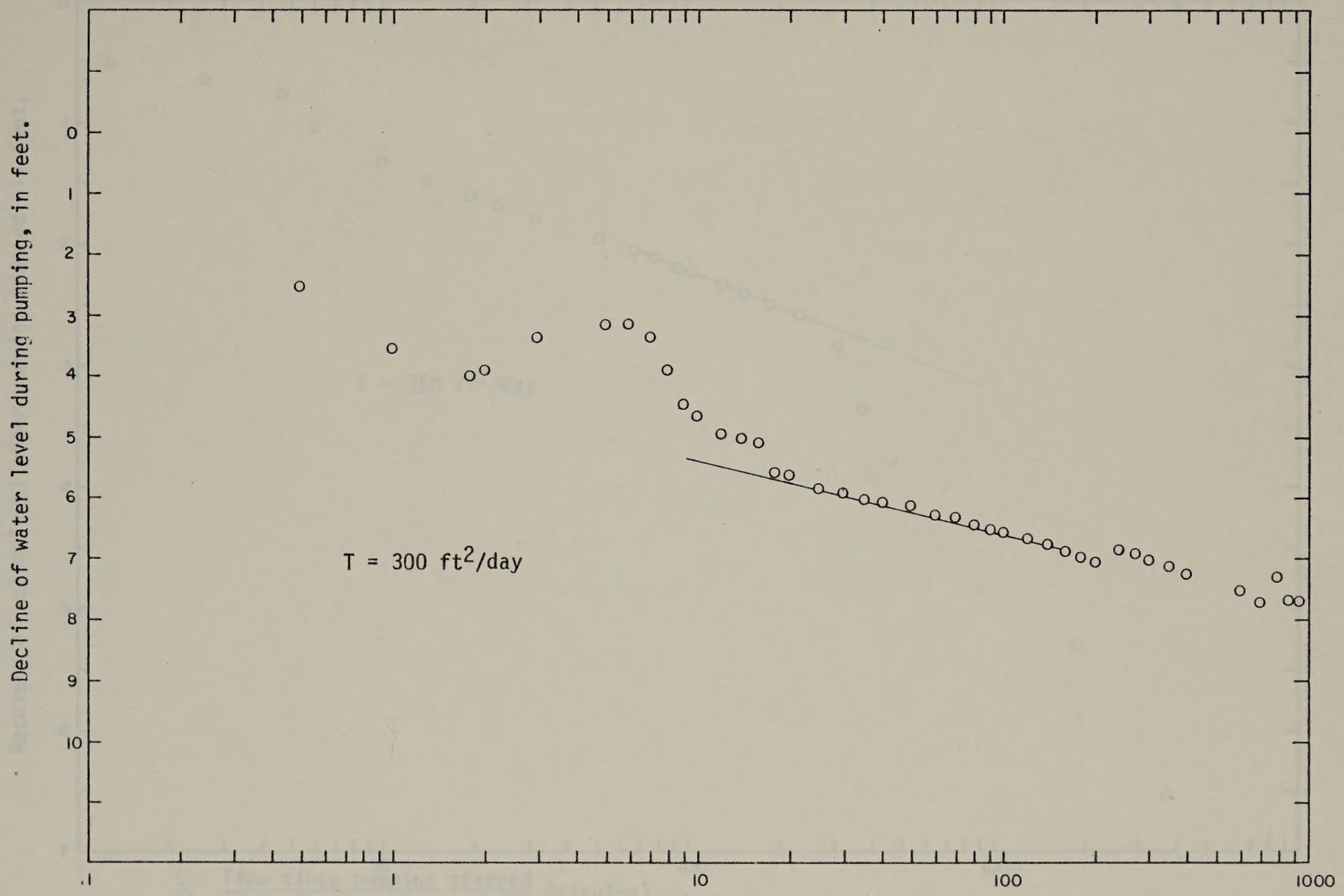


Drawdown and recovery curves.



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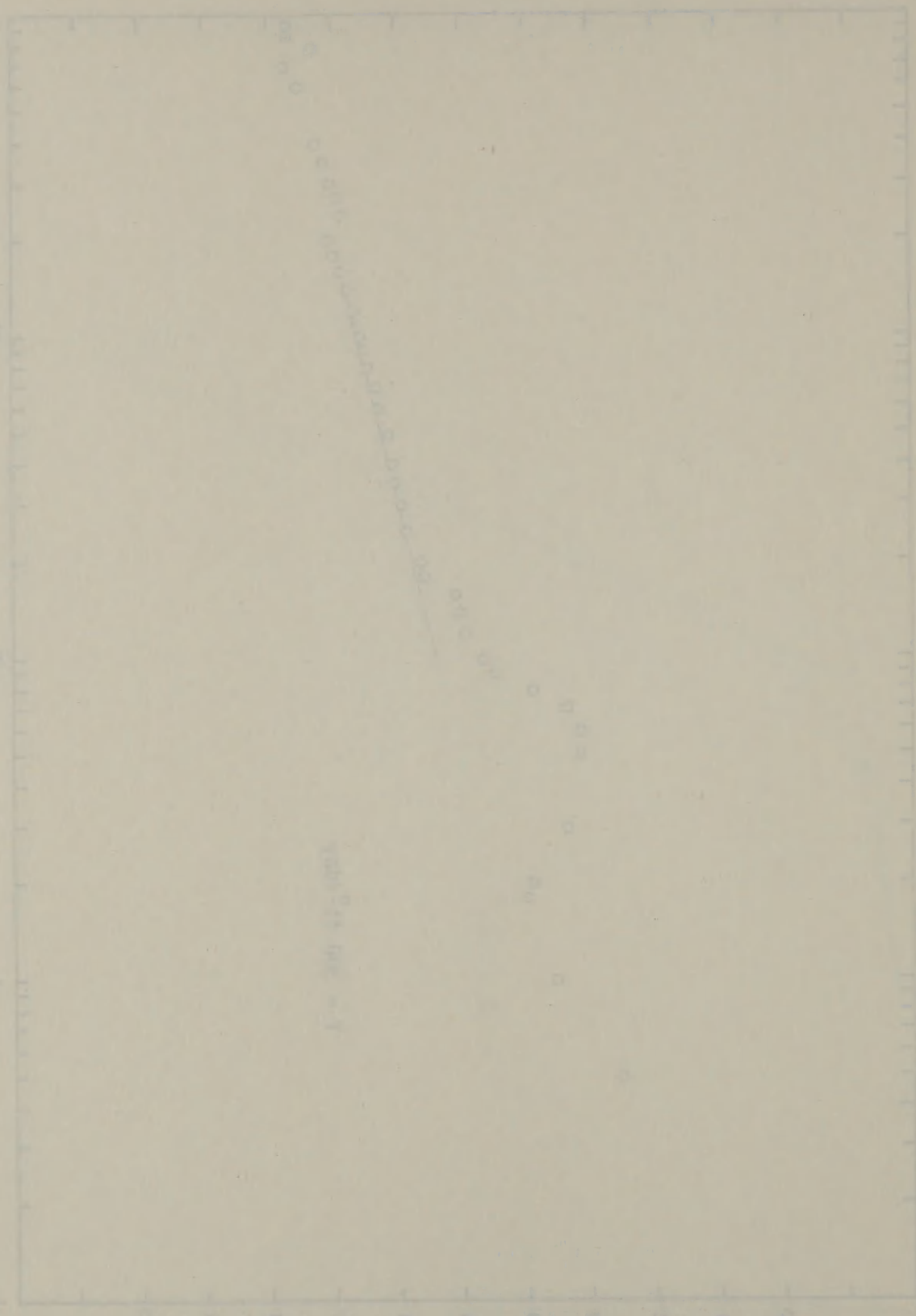
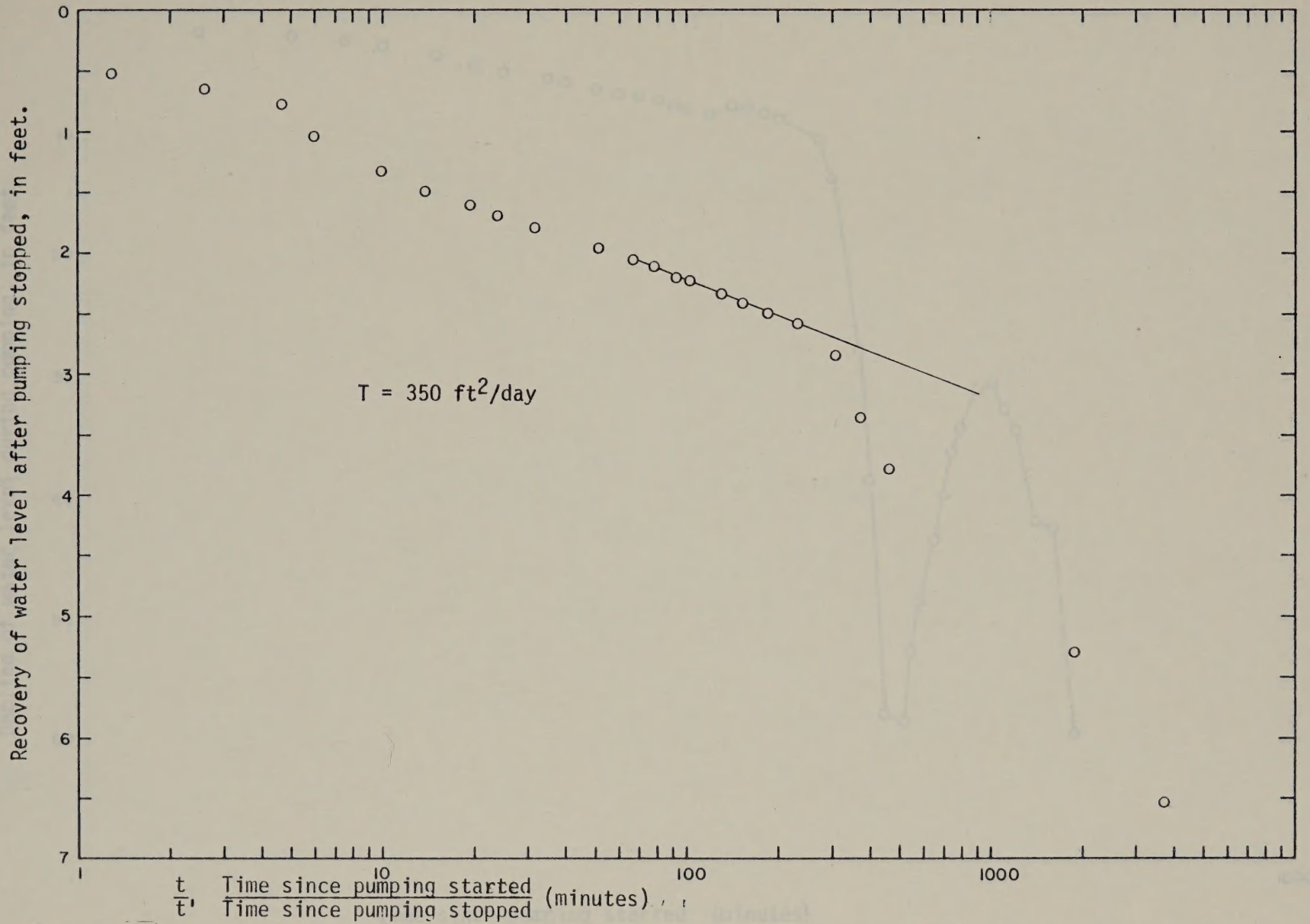
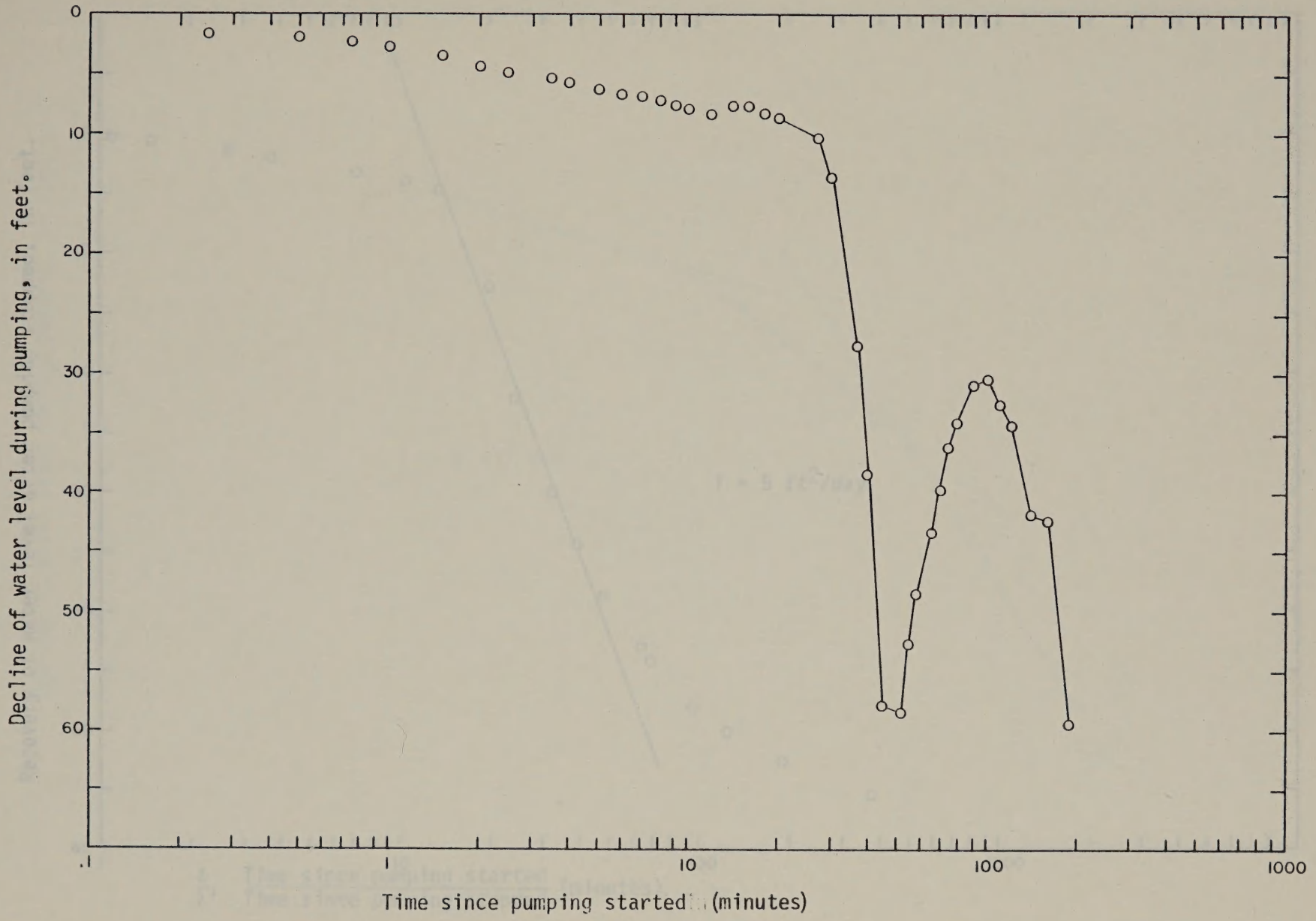


Drawdown and recovery curves.



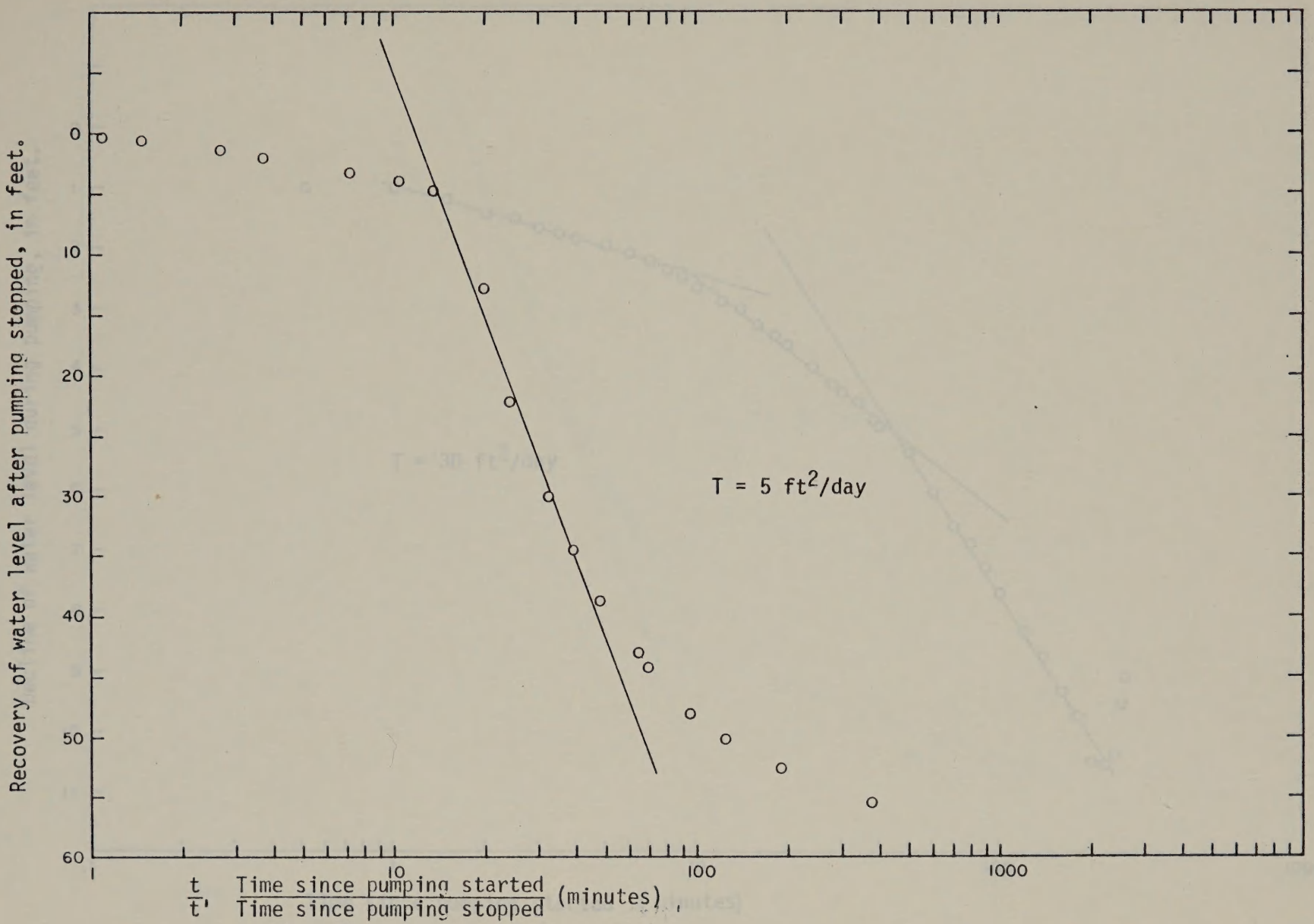
Plot of recovery data for well at 20.32.17.13.

Drawdown and recovery curves.



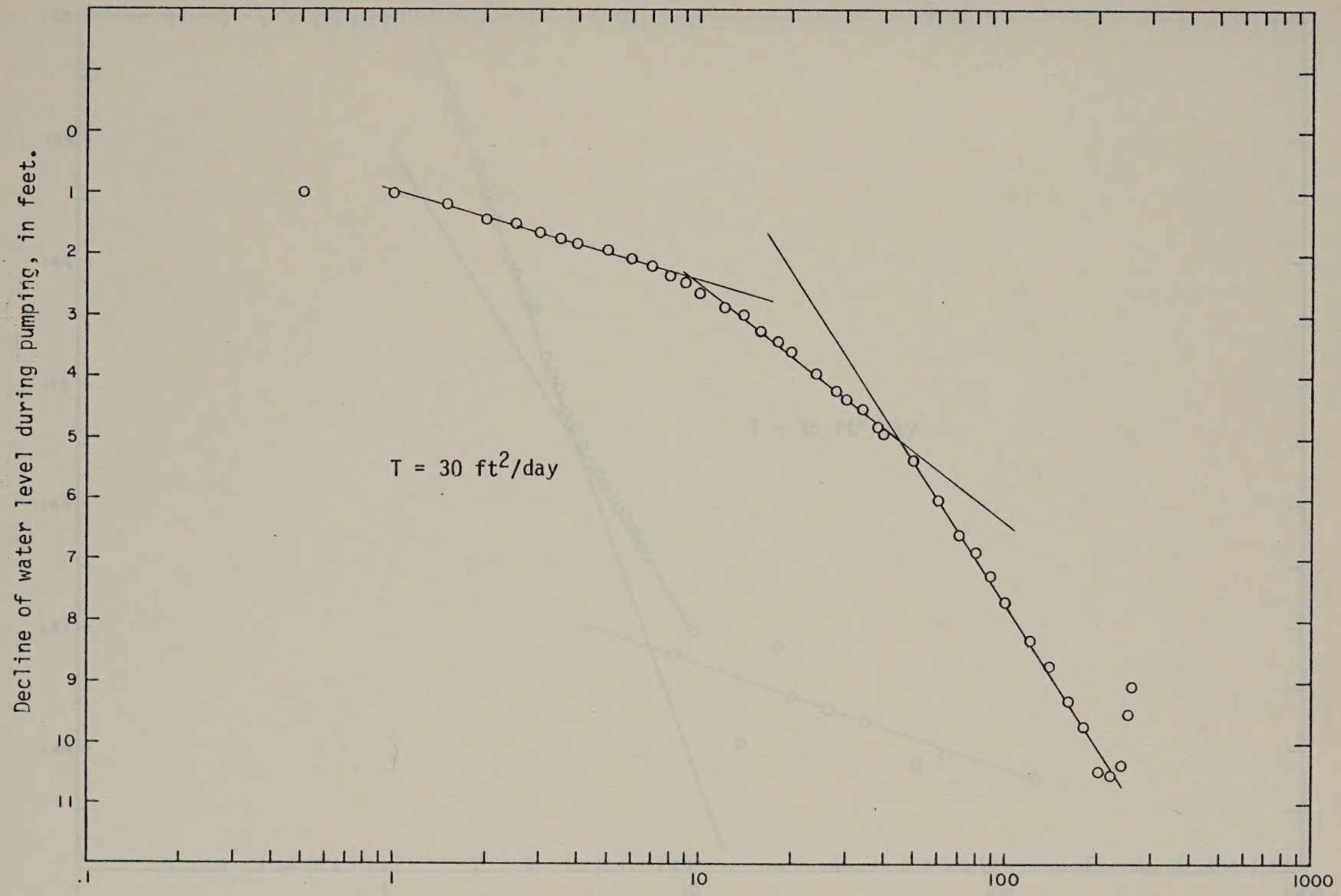
Plot of drawdown data for well at 20.32.22.33.

Drawdown and recovery curves.



Plot of recovery data for well at 20.32.22.33.

Drawdown and recovery curves.



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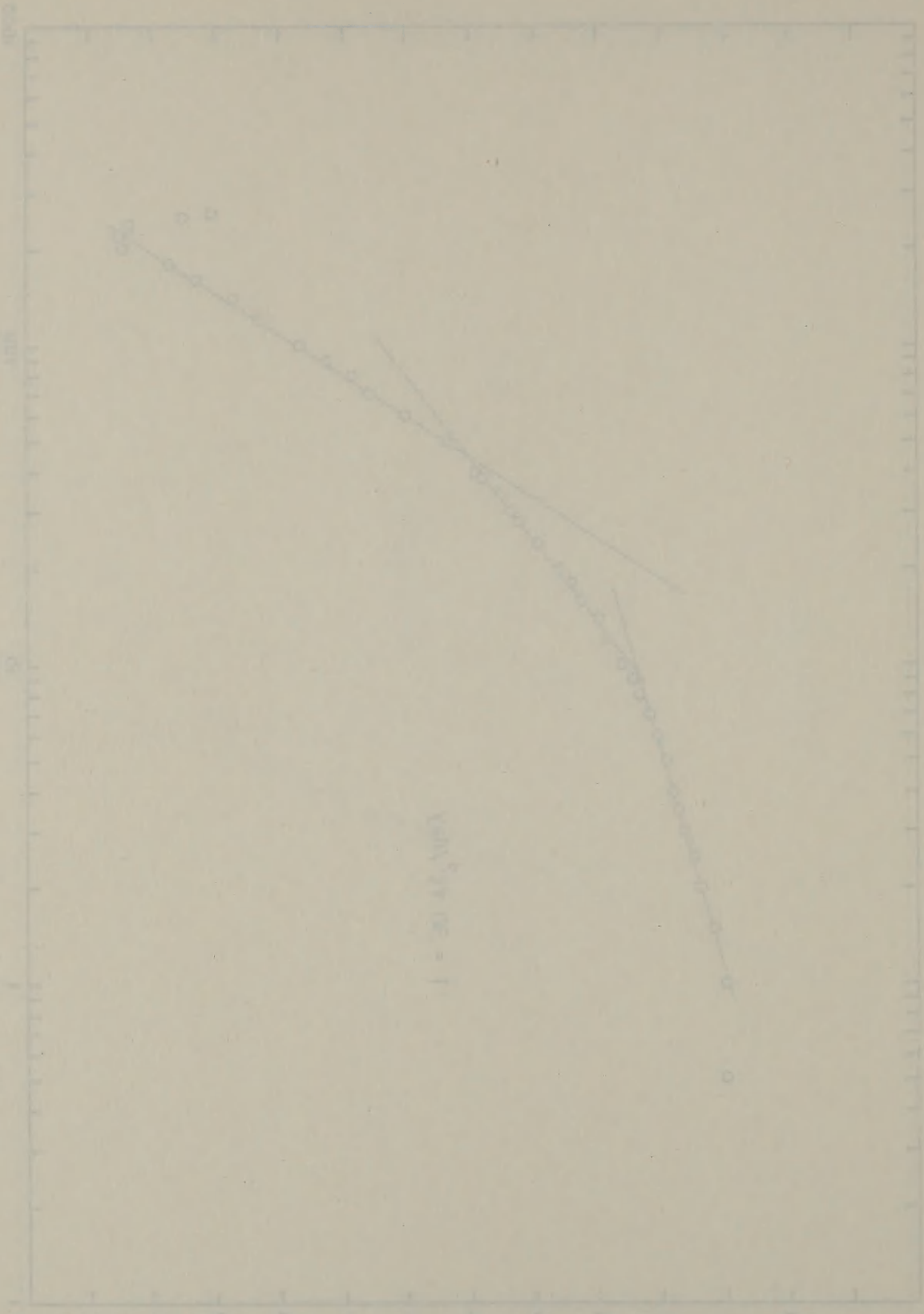
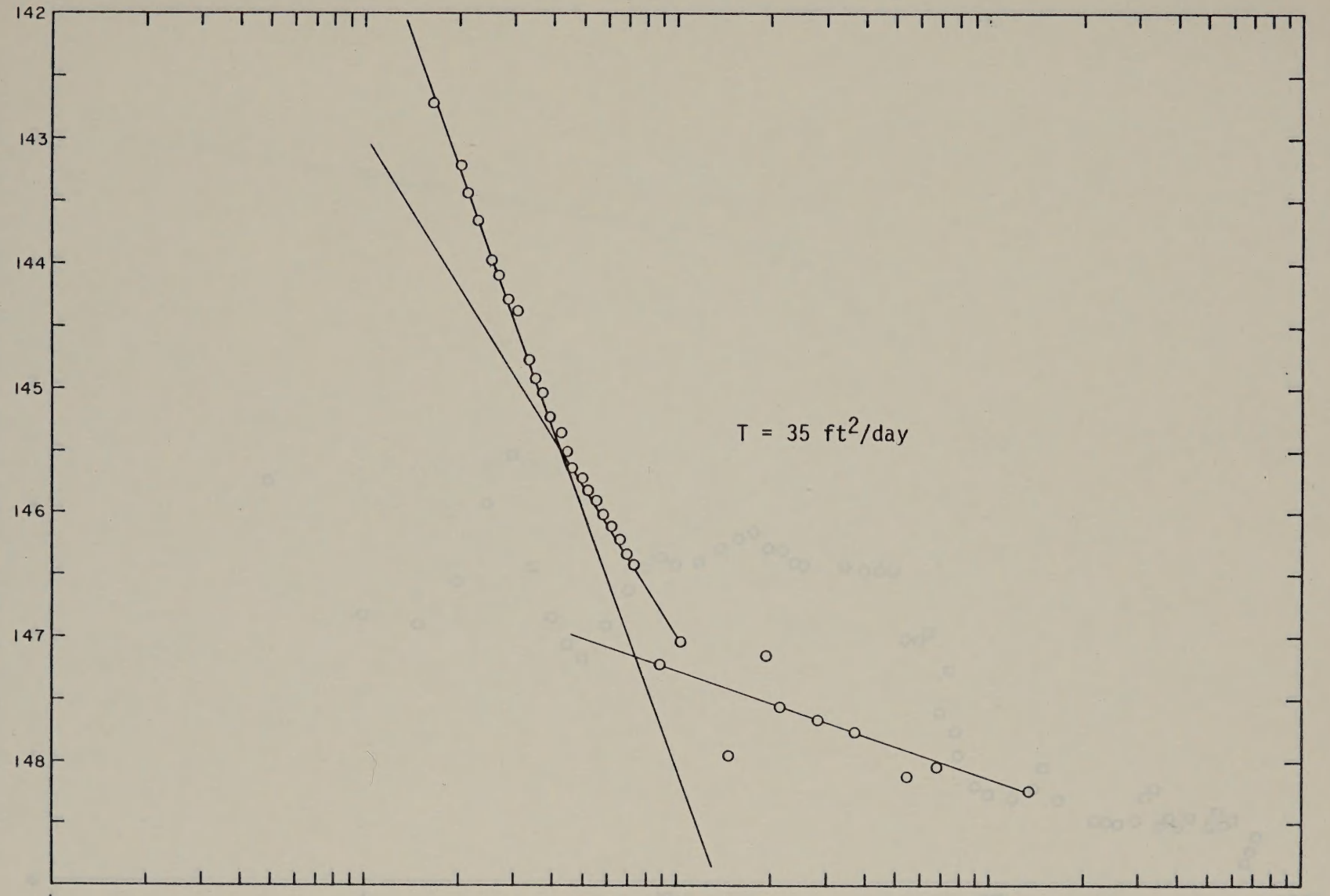


Drawdown and recovery curves.



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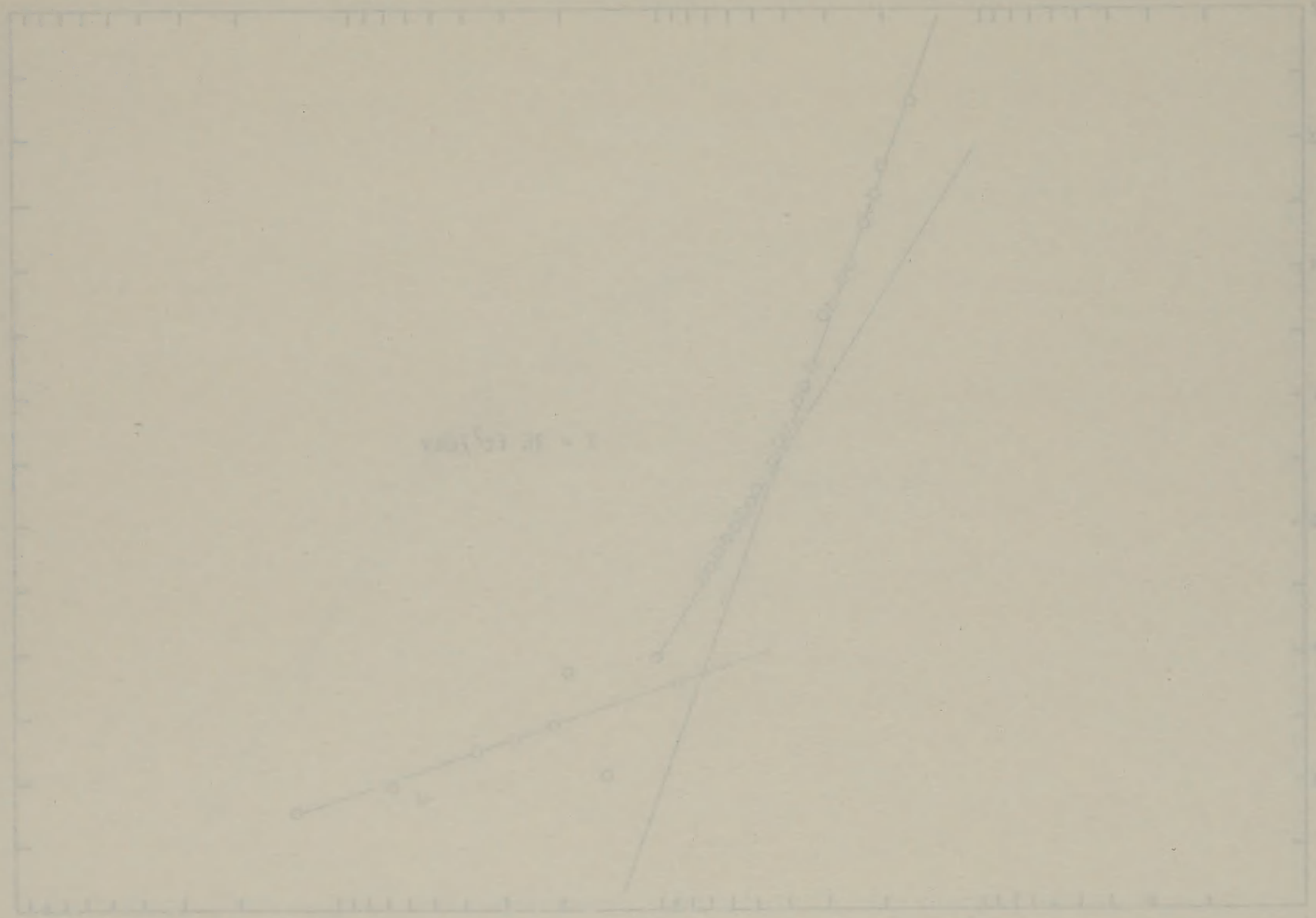
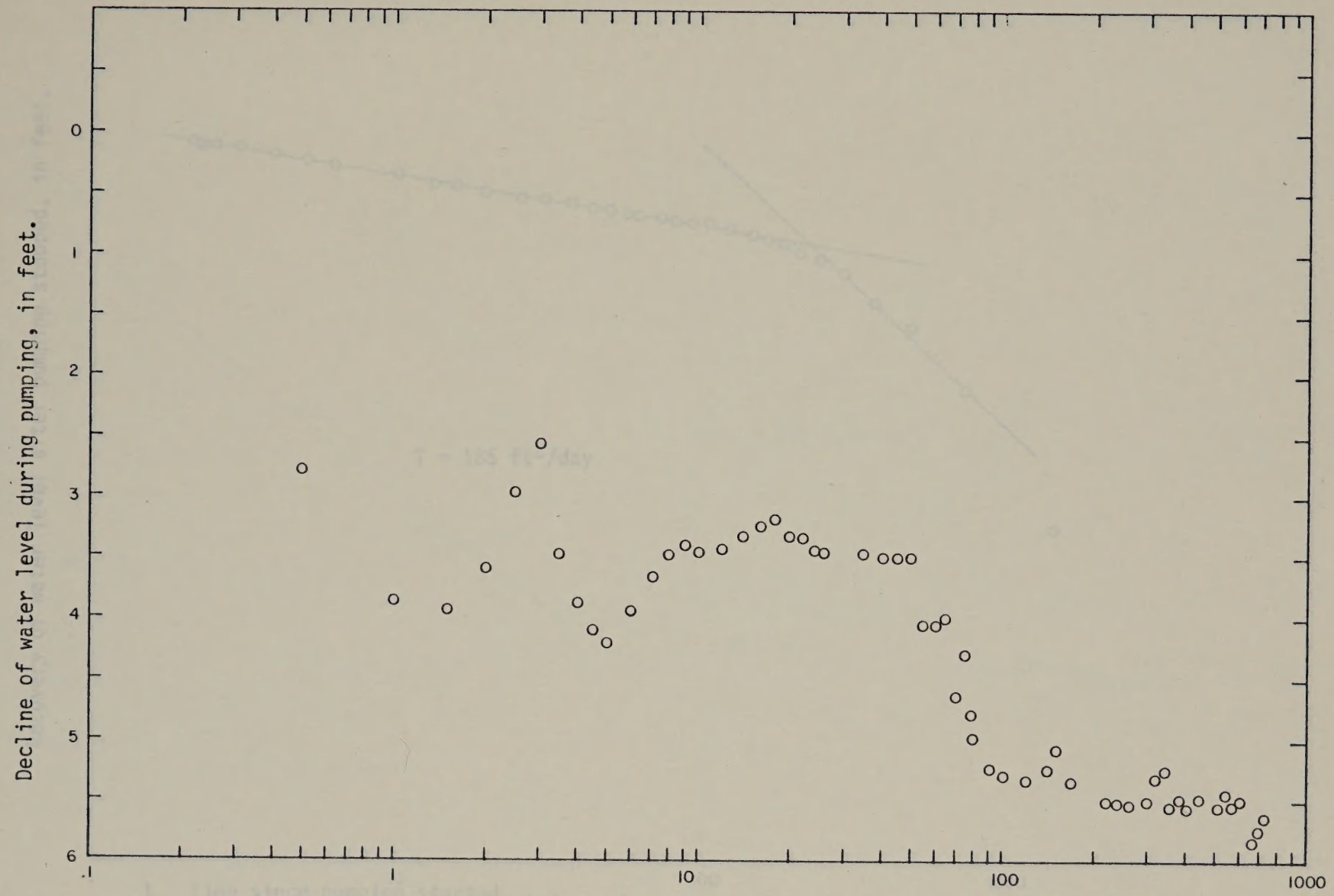
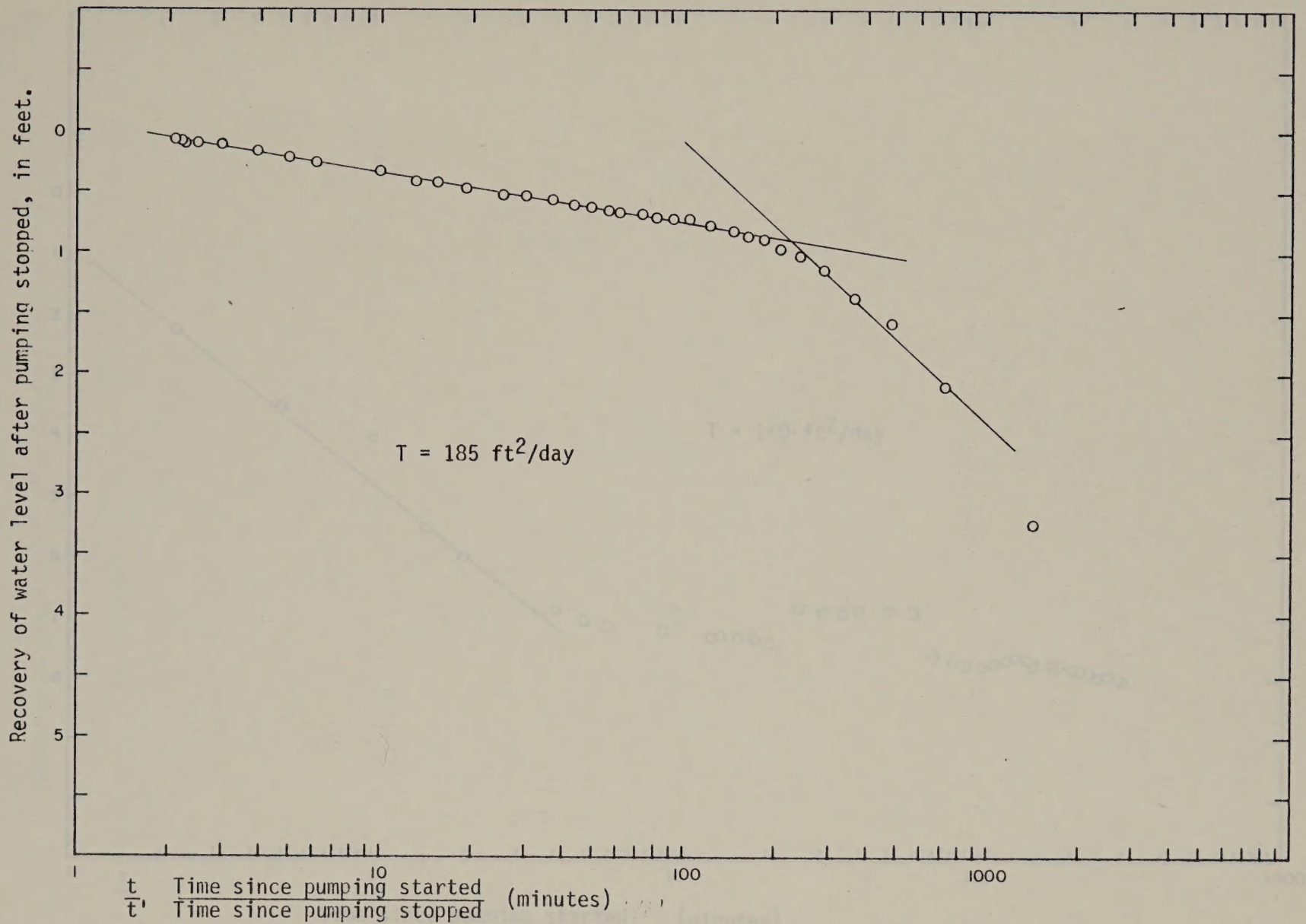


Drawdown and recovery curves.

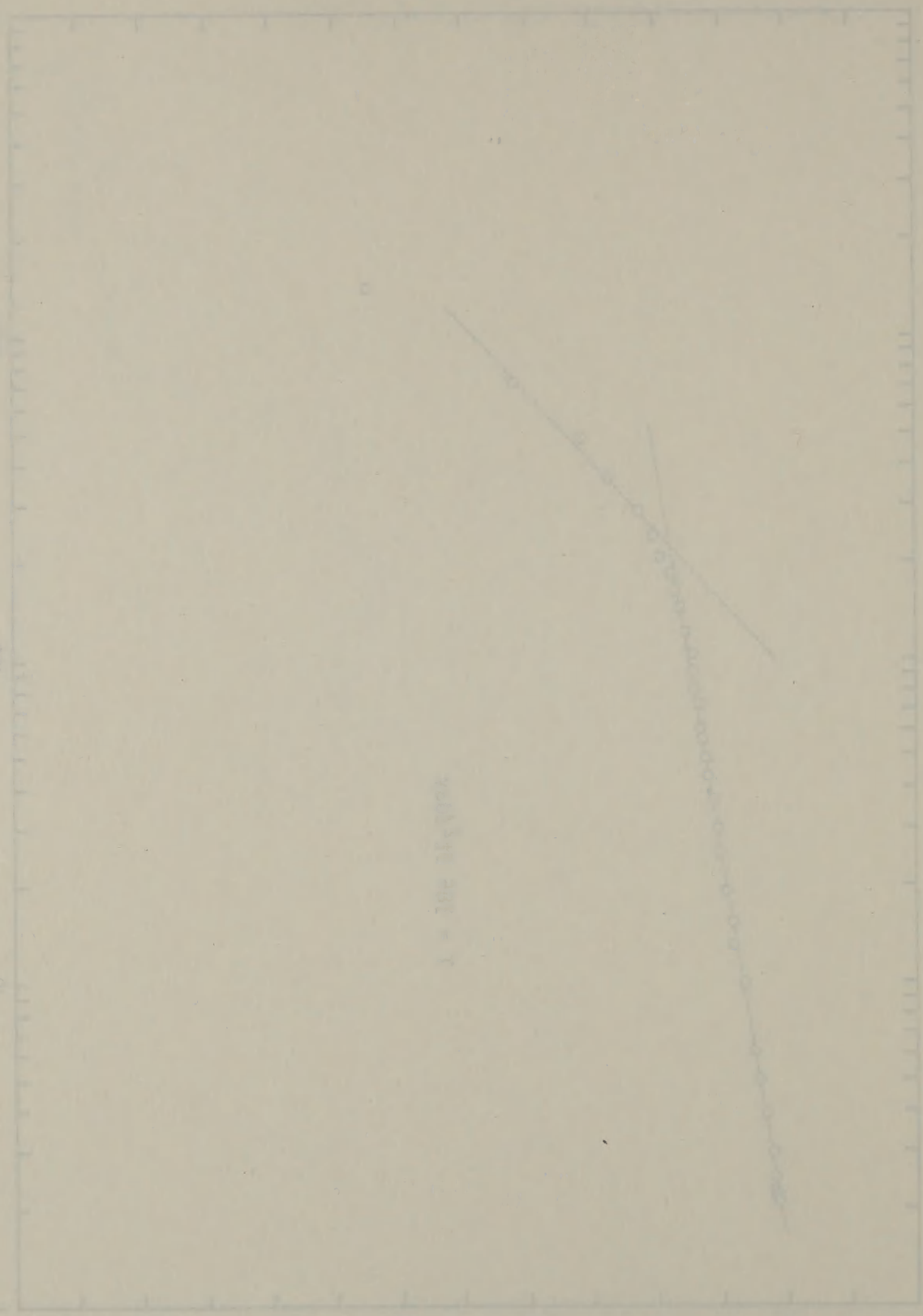


Plot of drawdown data for well at 23.29.18.14.

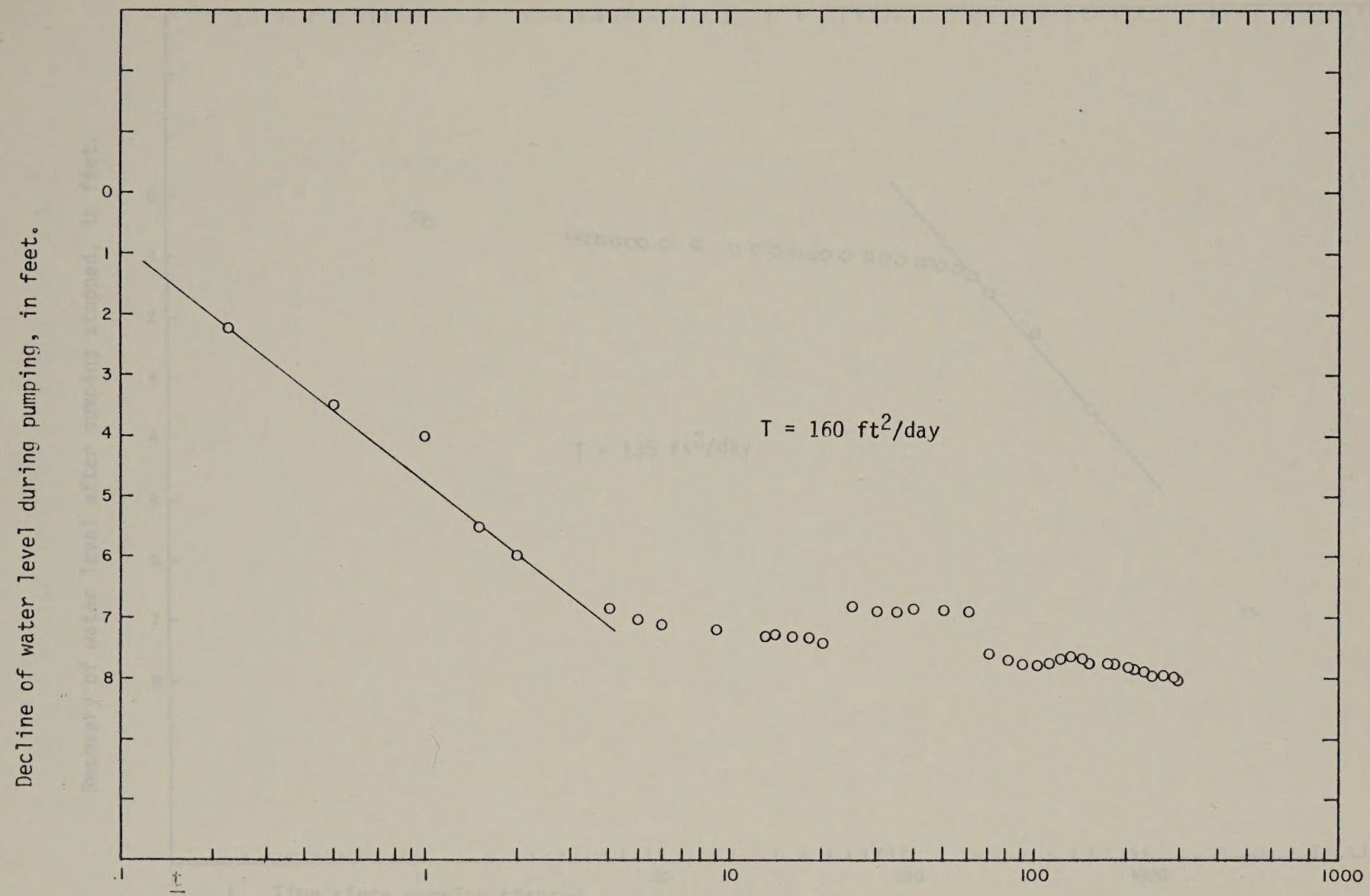
Drawdown and recovery curves.



Plot of recovery data for well at 23.29.18.14.

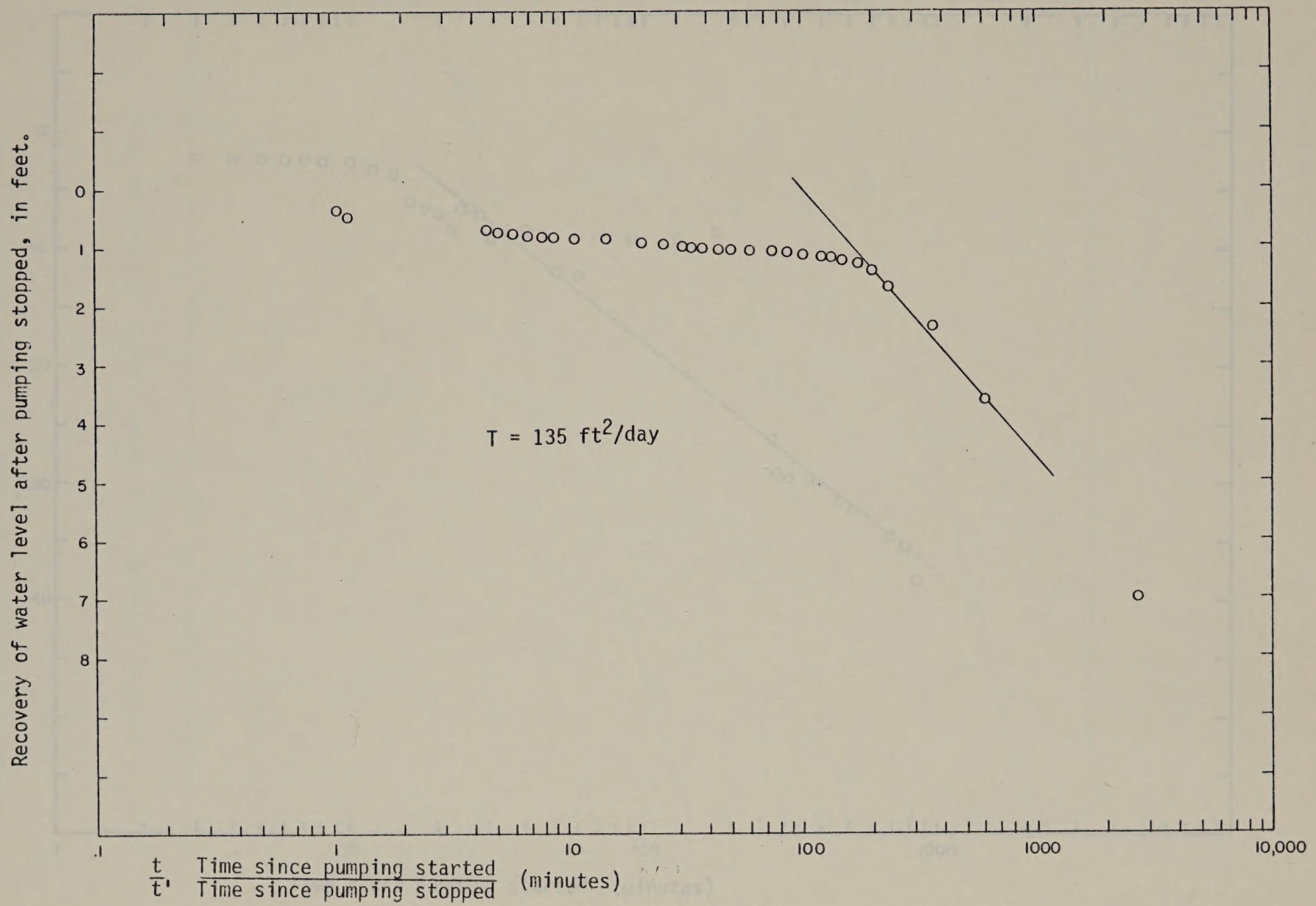


Drawdown and recovery curves.



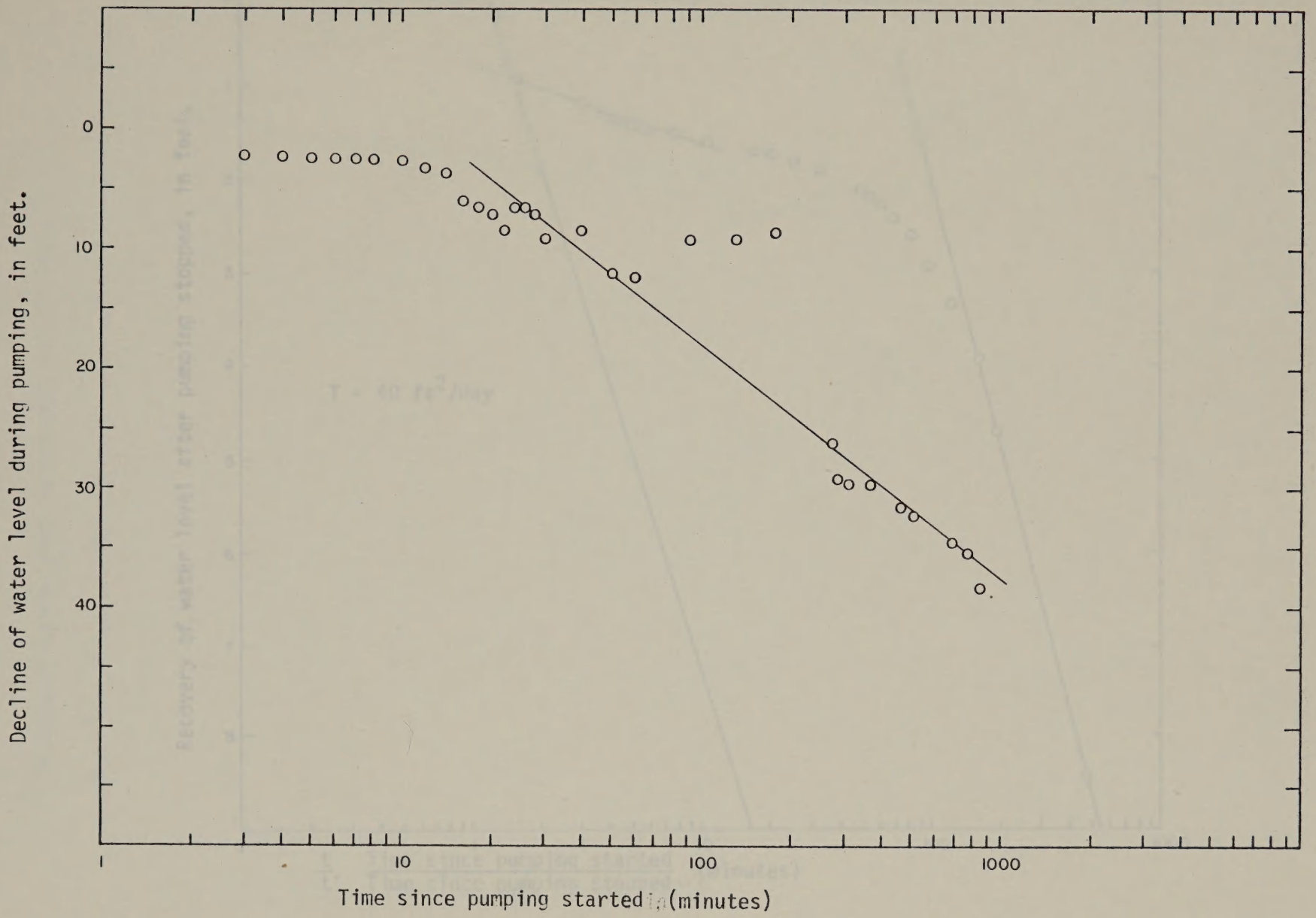
Plot of drawdown data for well at 23.29.20.33.

Drawdown and recovery curves.

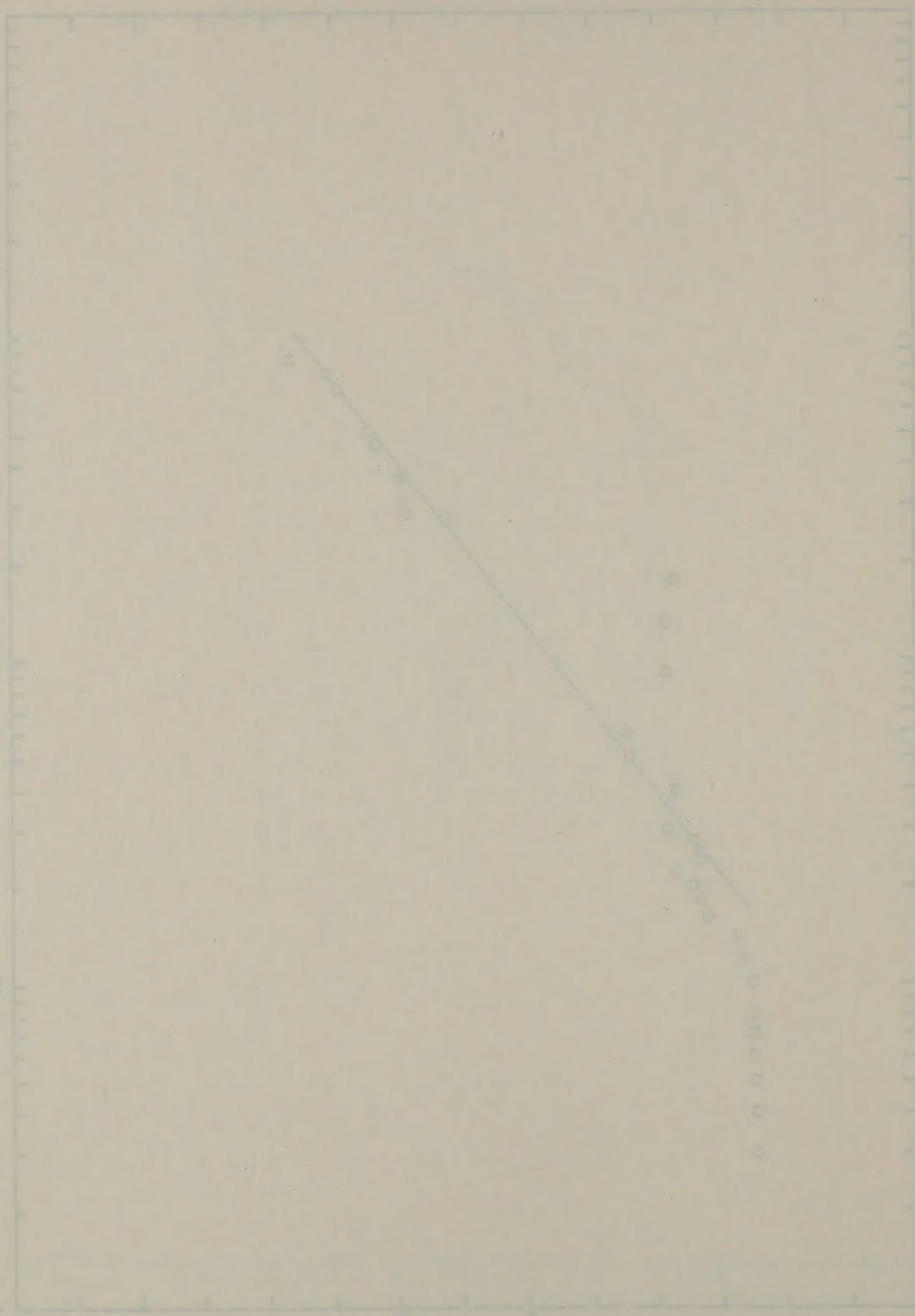


Plot of recovery data for well at 23.29.20.33.

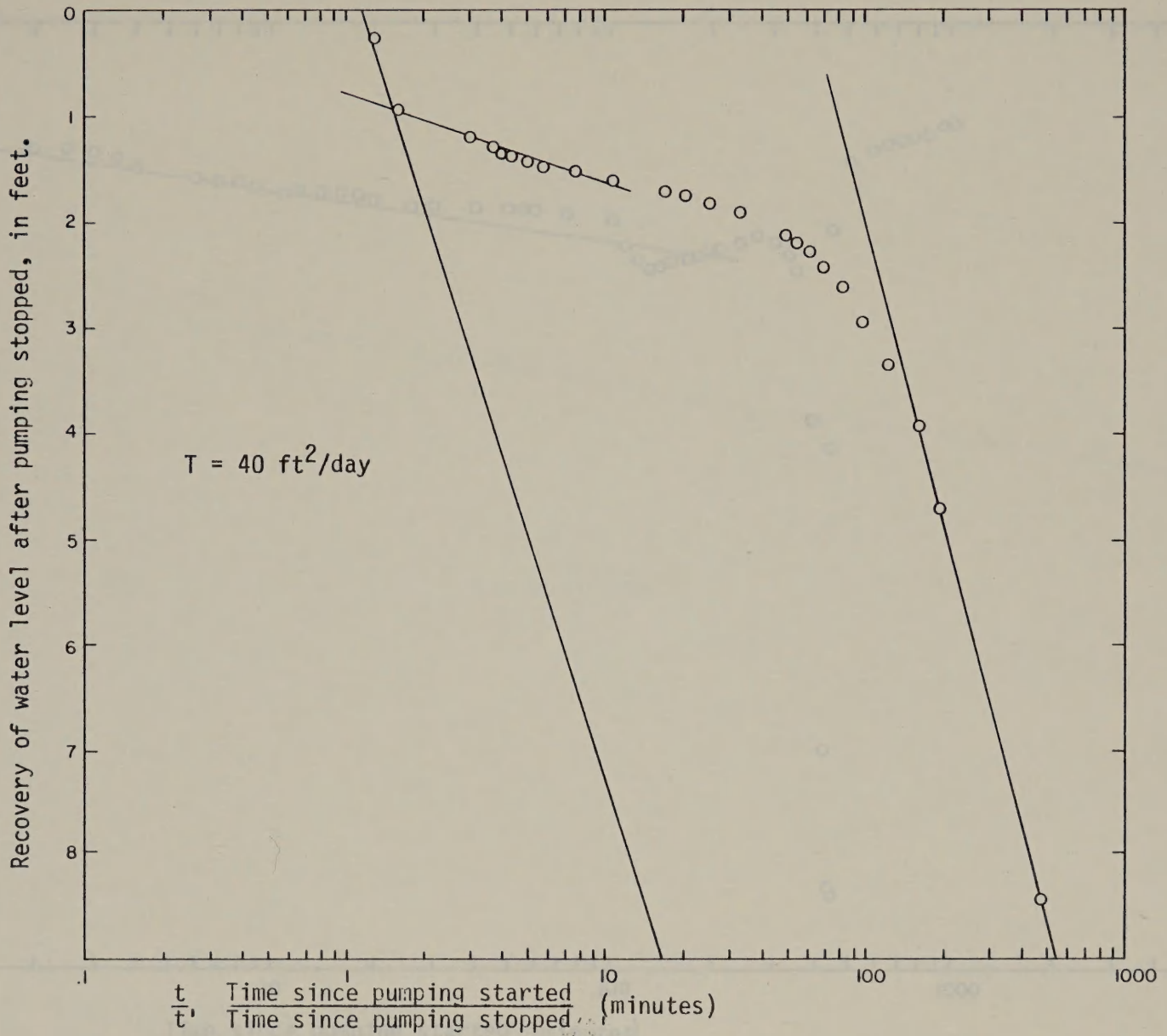
Drawdown and recovery curves.



Plot of drawdown data for well at 23.29.28.41.
Tested December 15 through 18, 1978.



Drawdown and recovery curves.



Plot of recovery data for well at 23.29.28.41.
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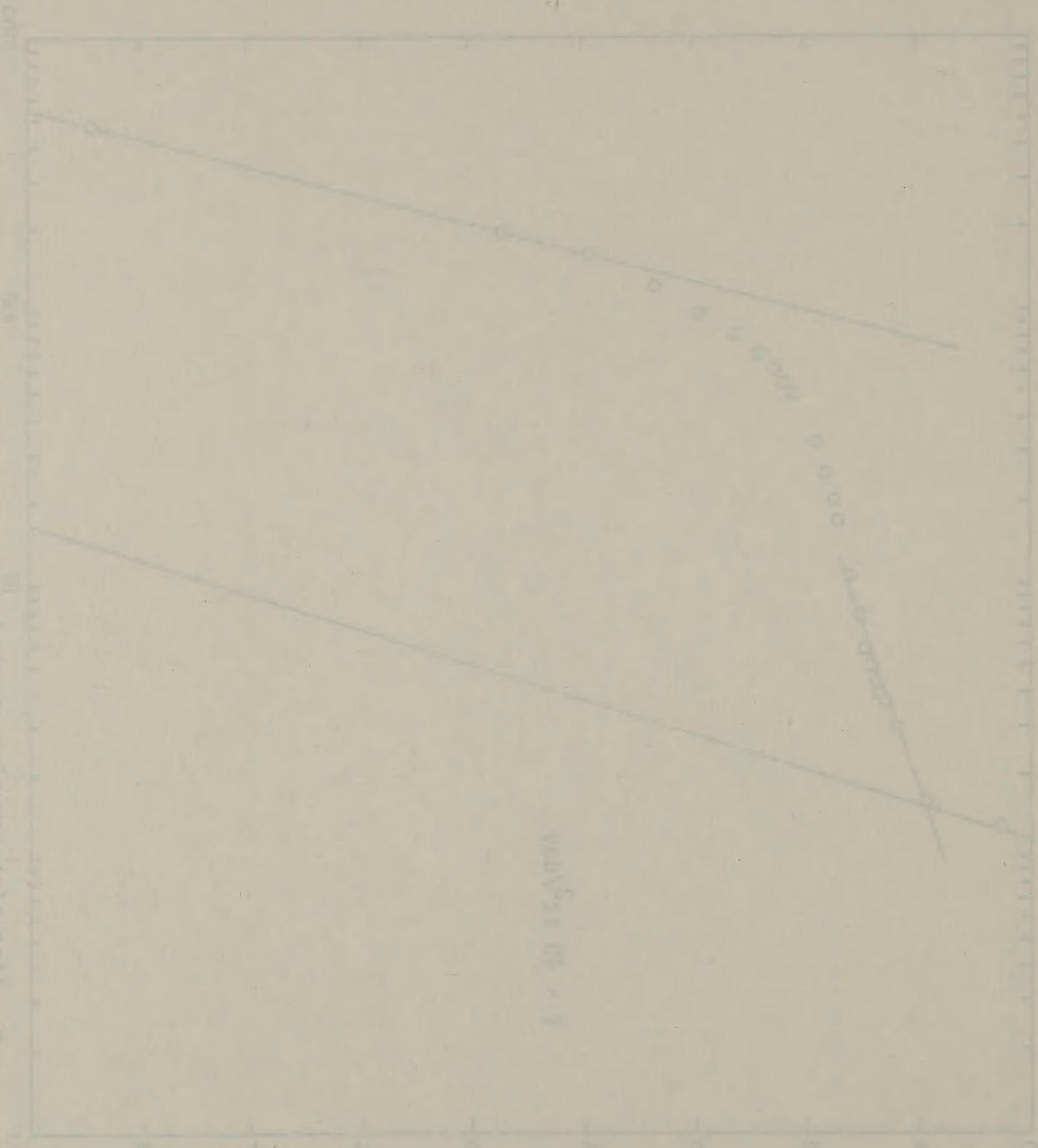
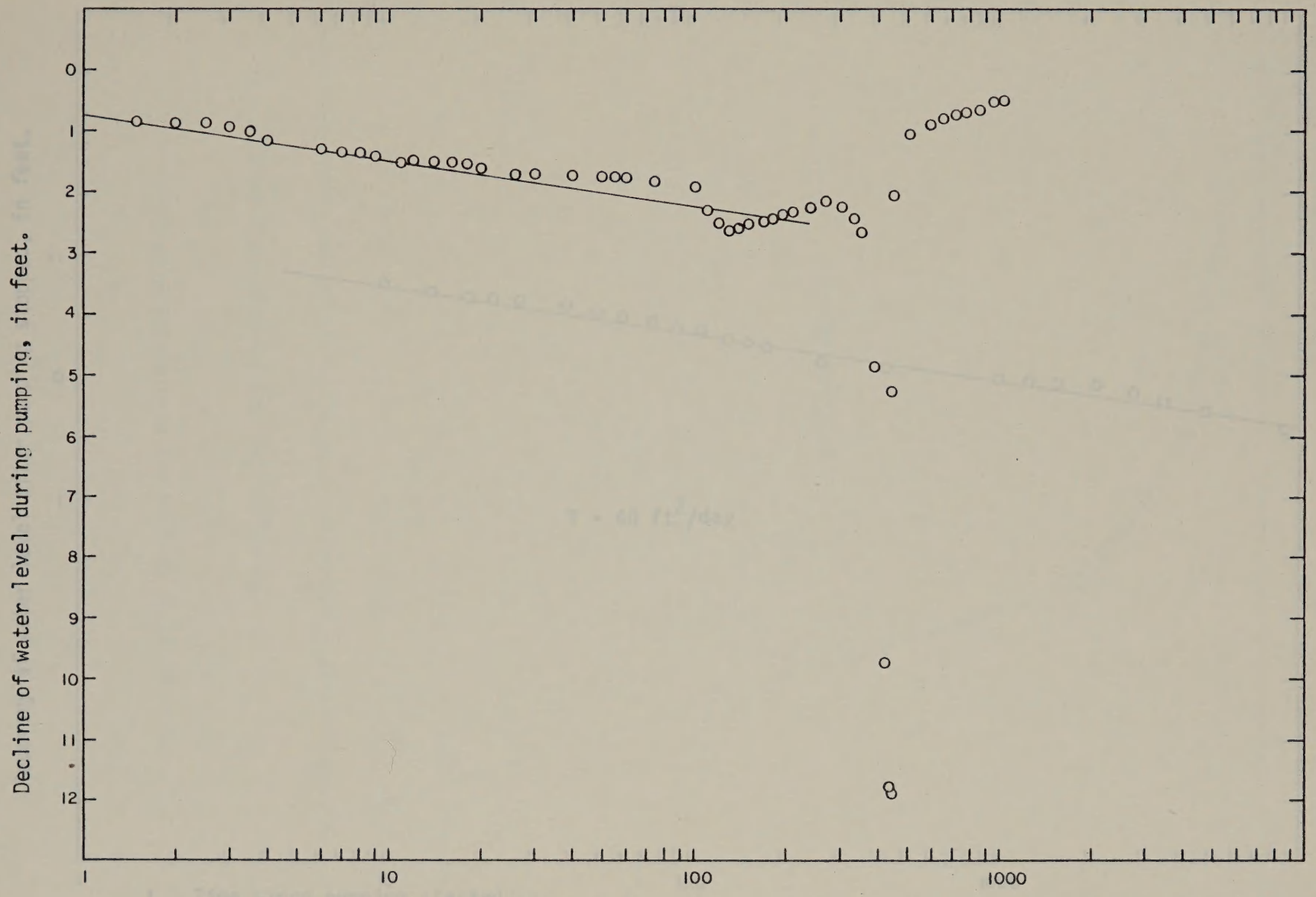
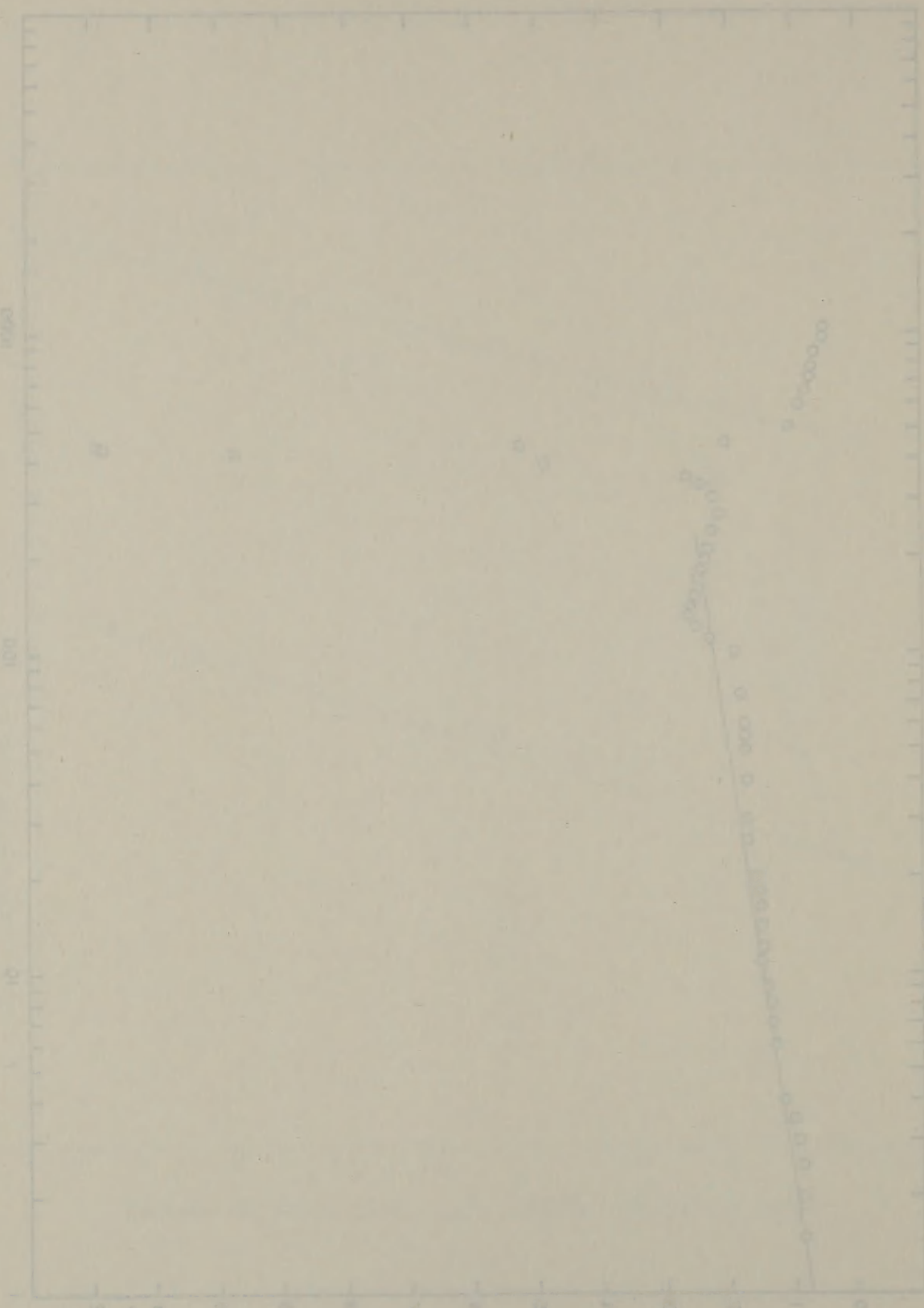


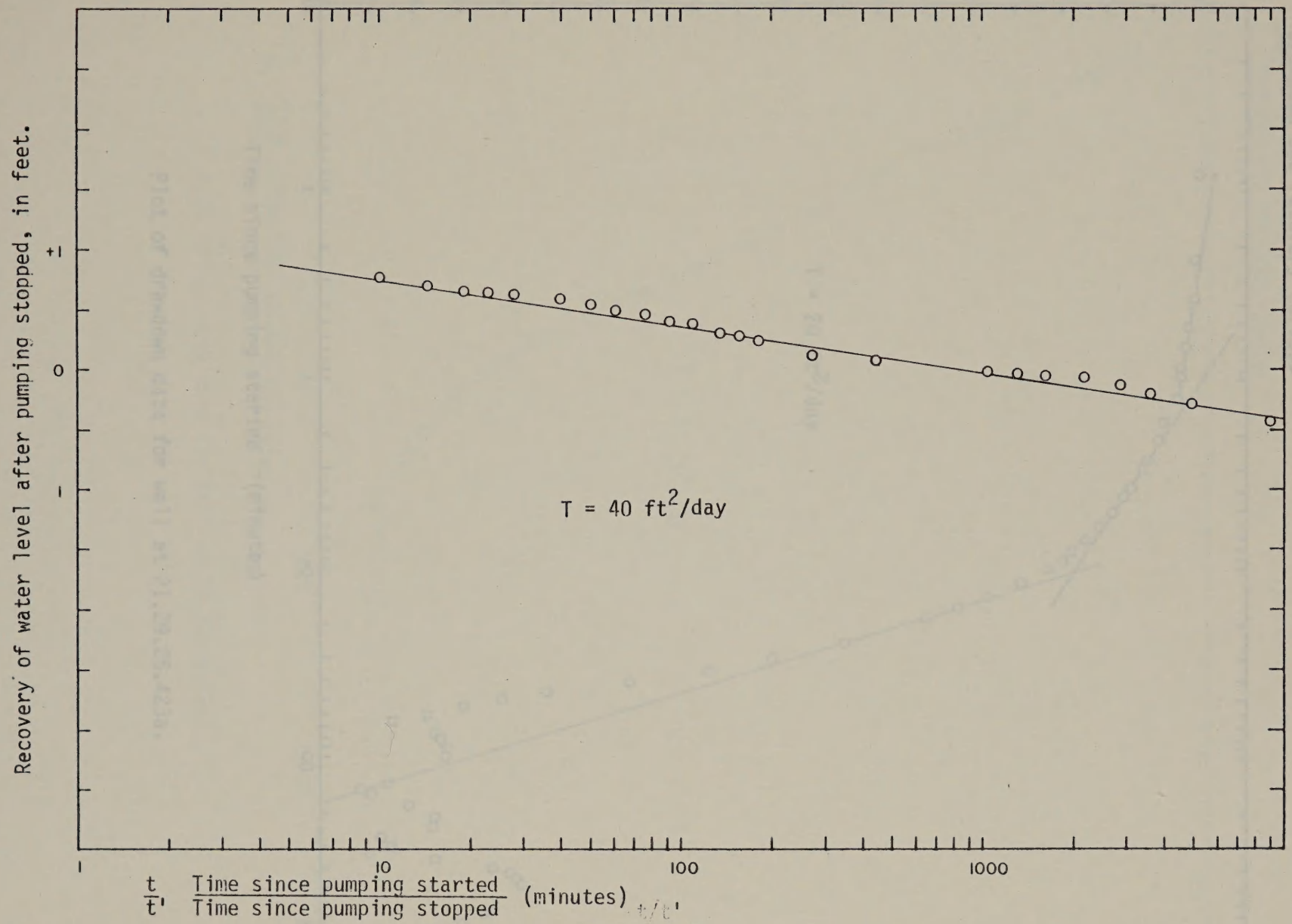
Drawdown and recovery curves.



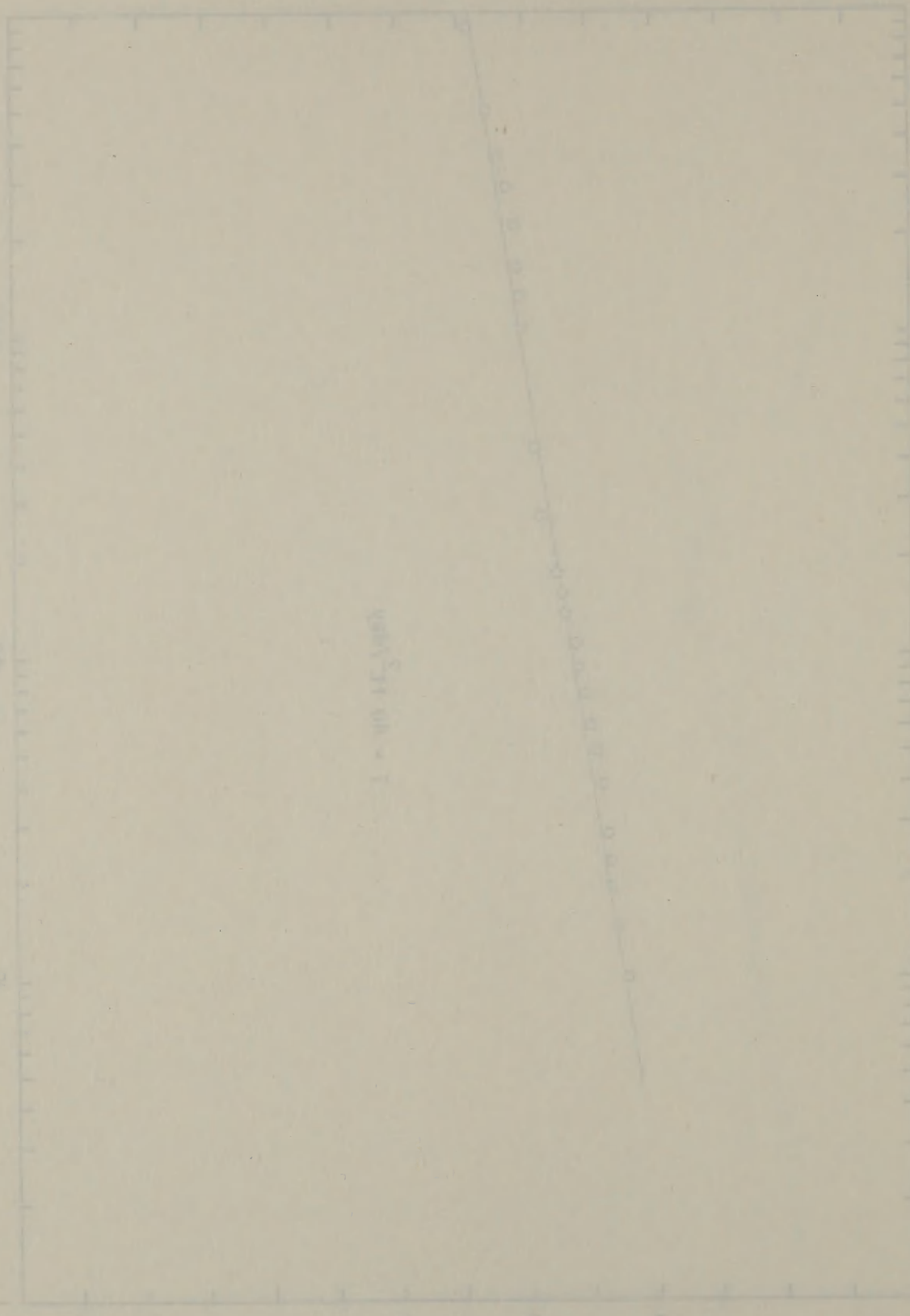
Plot of drawdown data for well at 23.29.28.41.
Tested January 9 and 10, 1979.



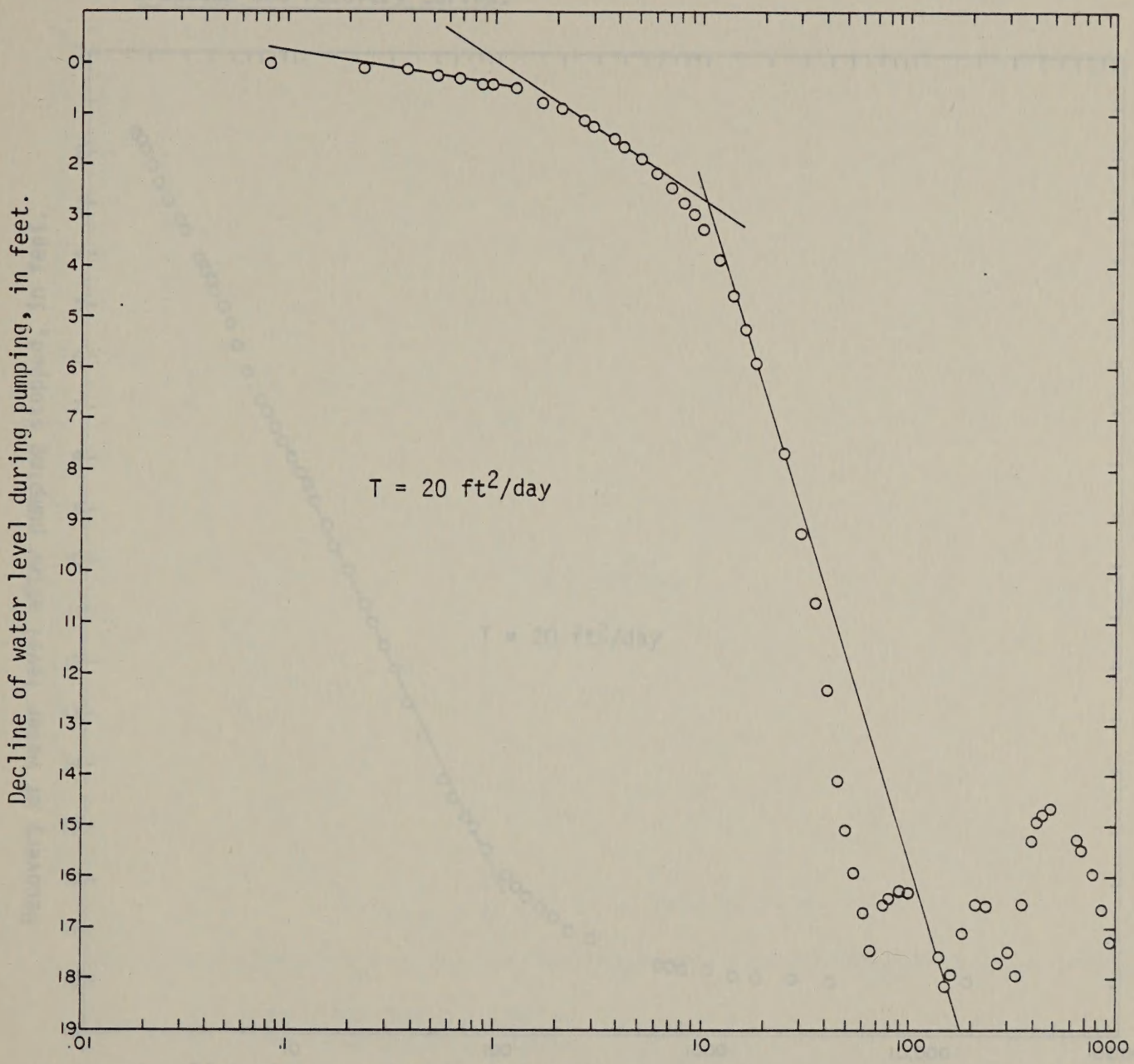
Drawdown and recovery curves.



Plot of recovery data for well at 23.29.28.41.
Tested January 9 and 10, 1979.

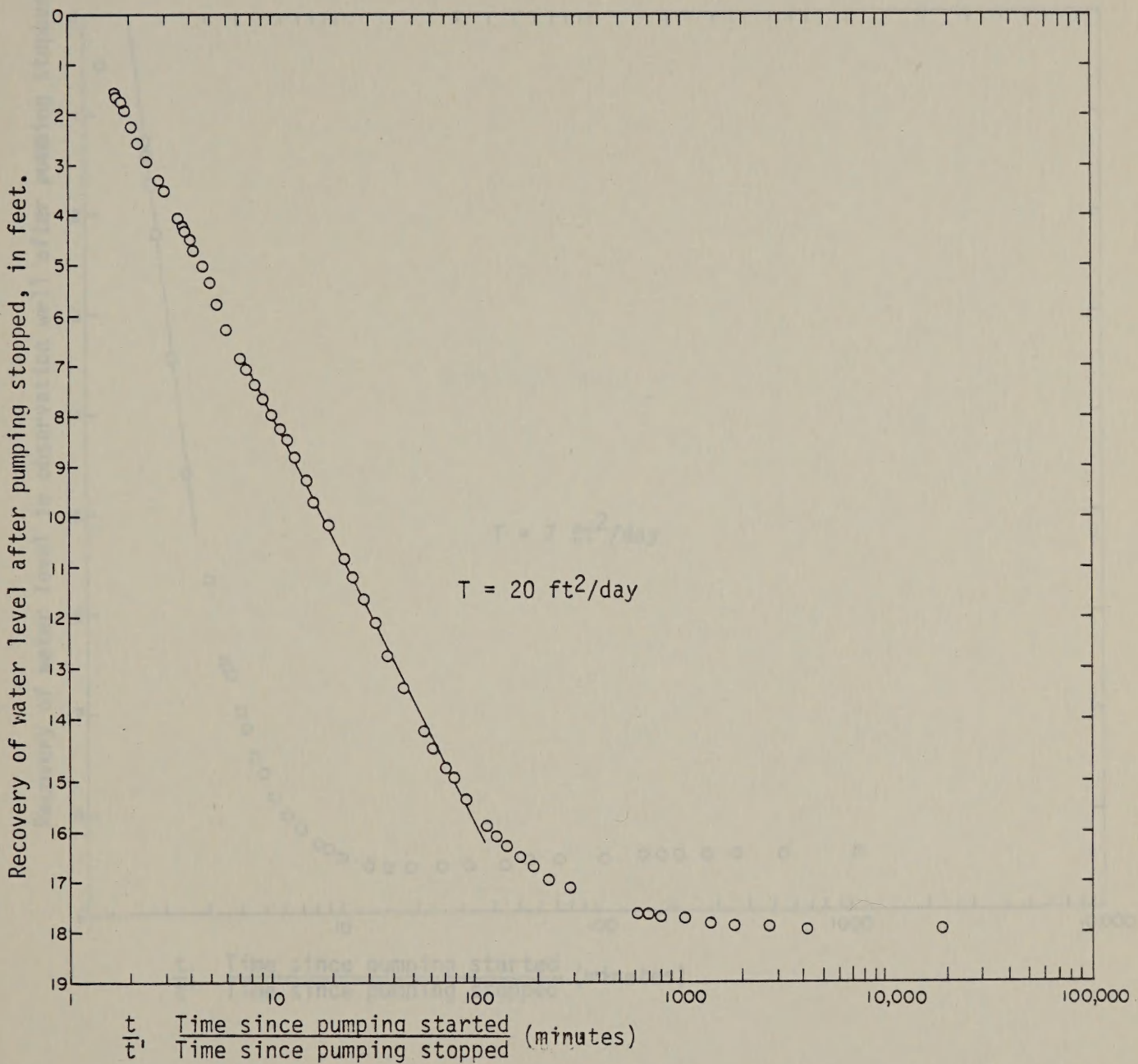


Drawdown and recovery curves.

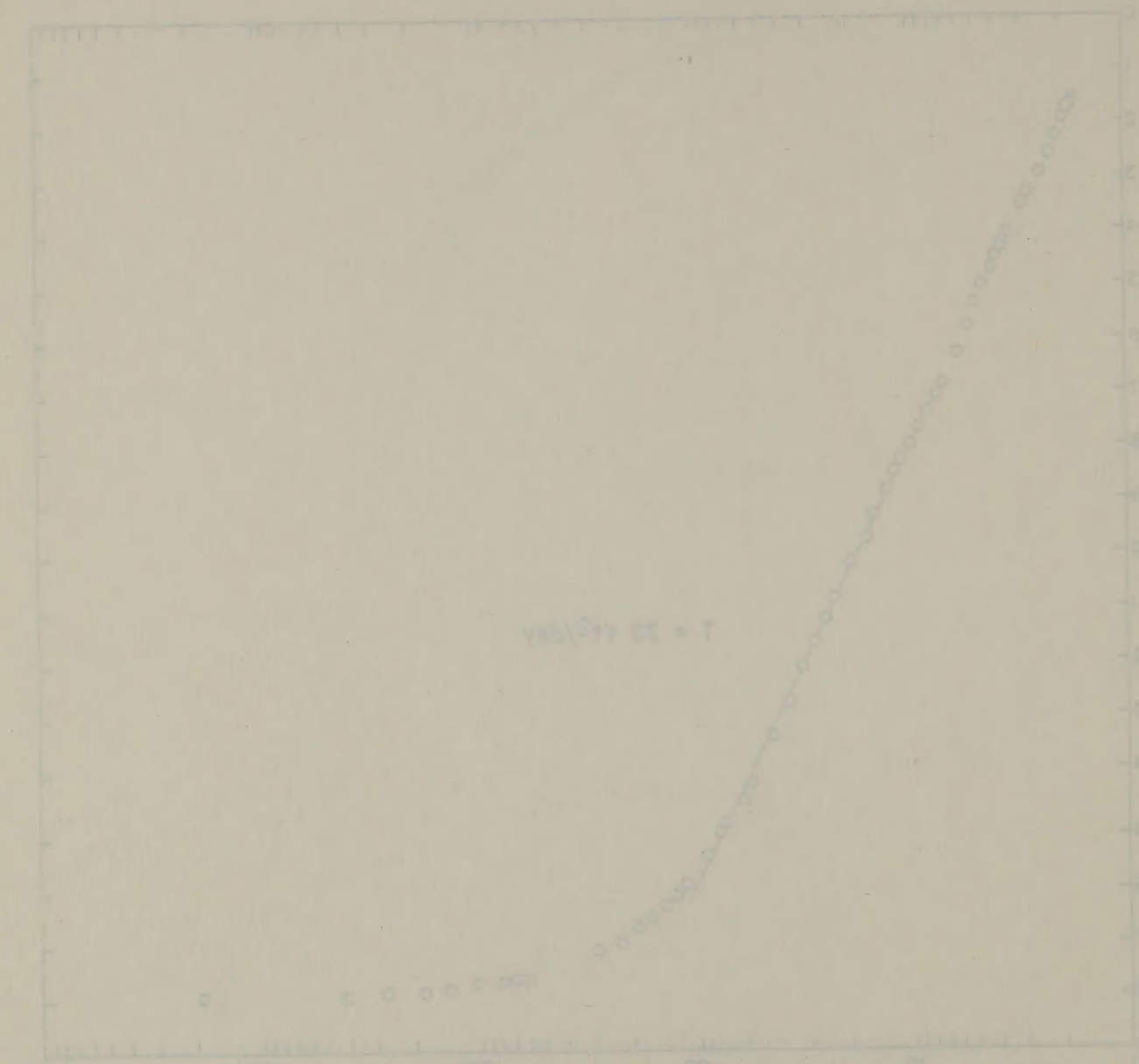


Plot of drawdown data for well at 21.29.25.423a.

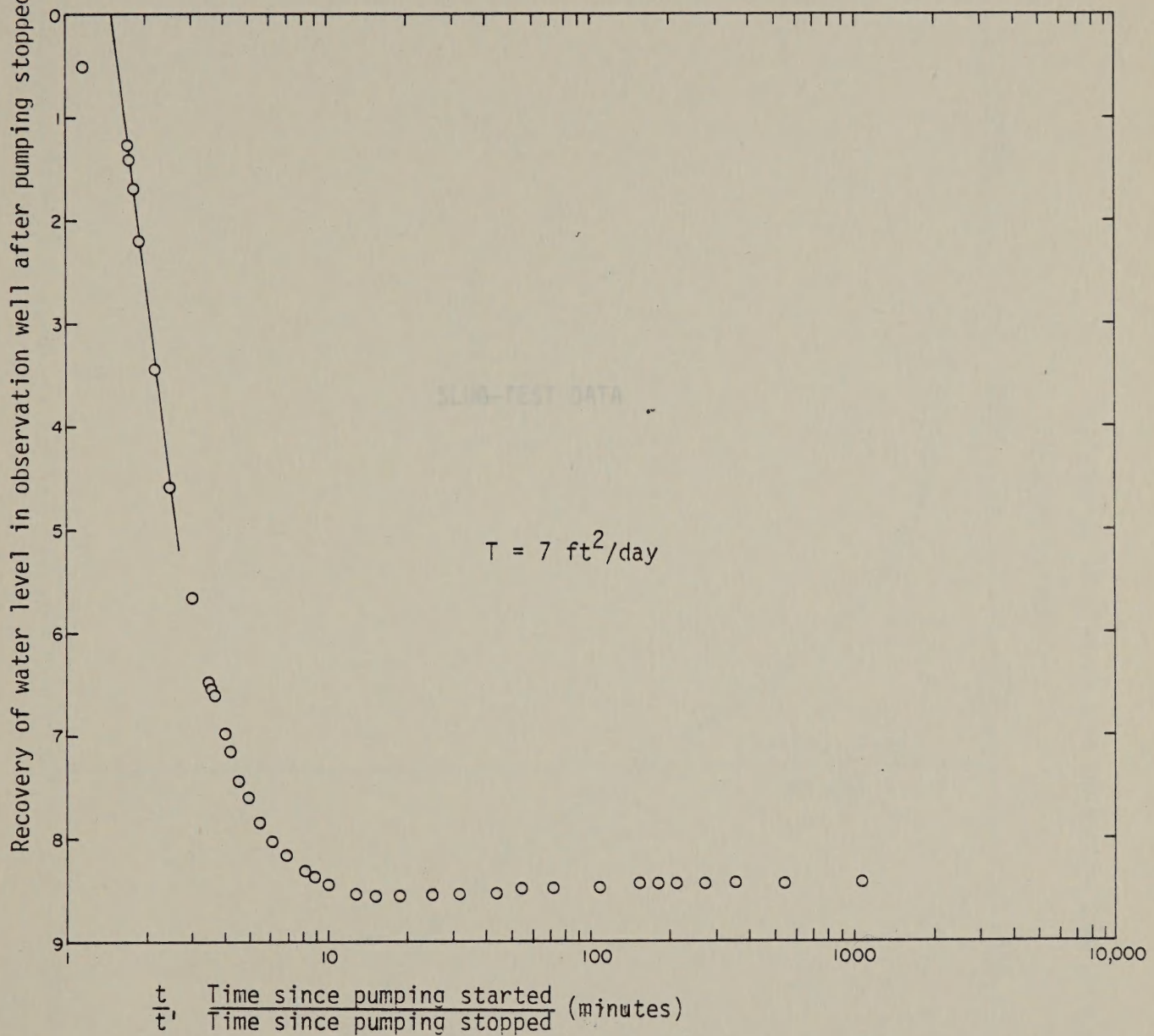
Drawdown and recovery curves.



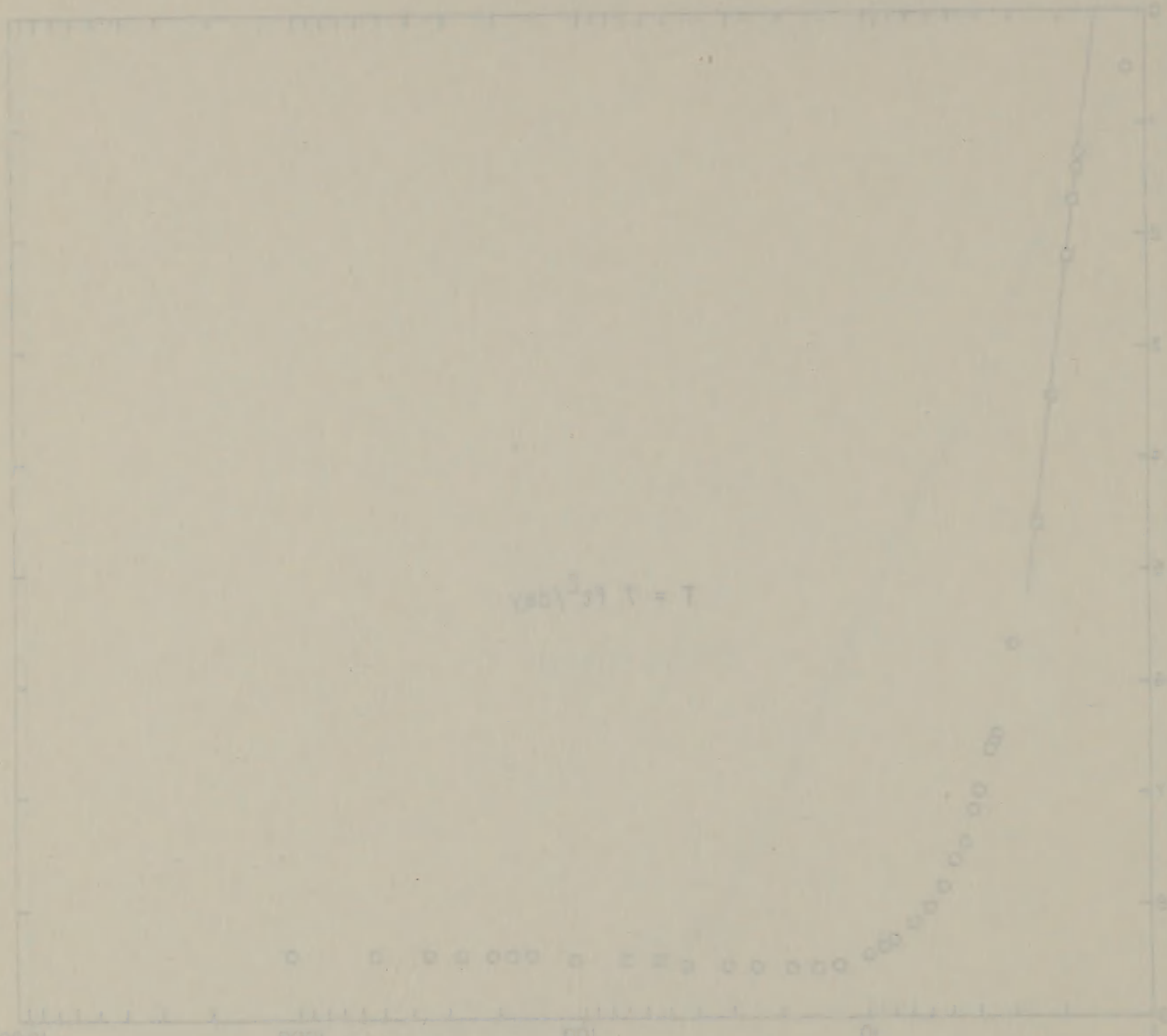
Plot of recovery data for well at 21.29.25.423a.



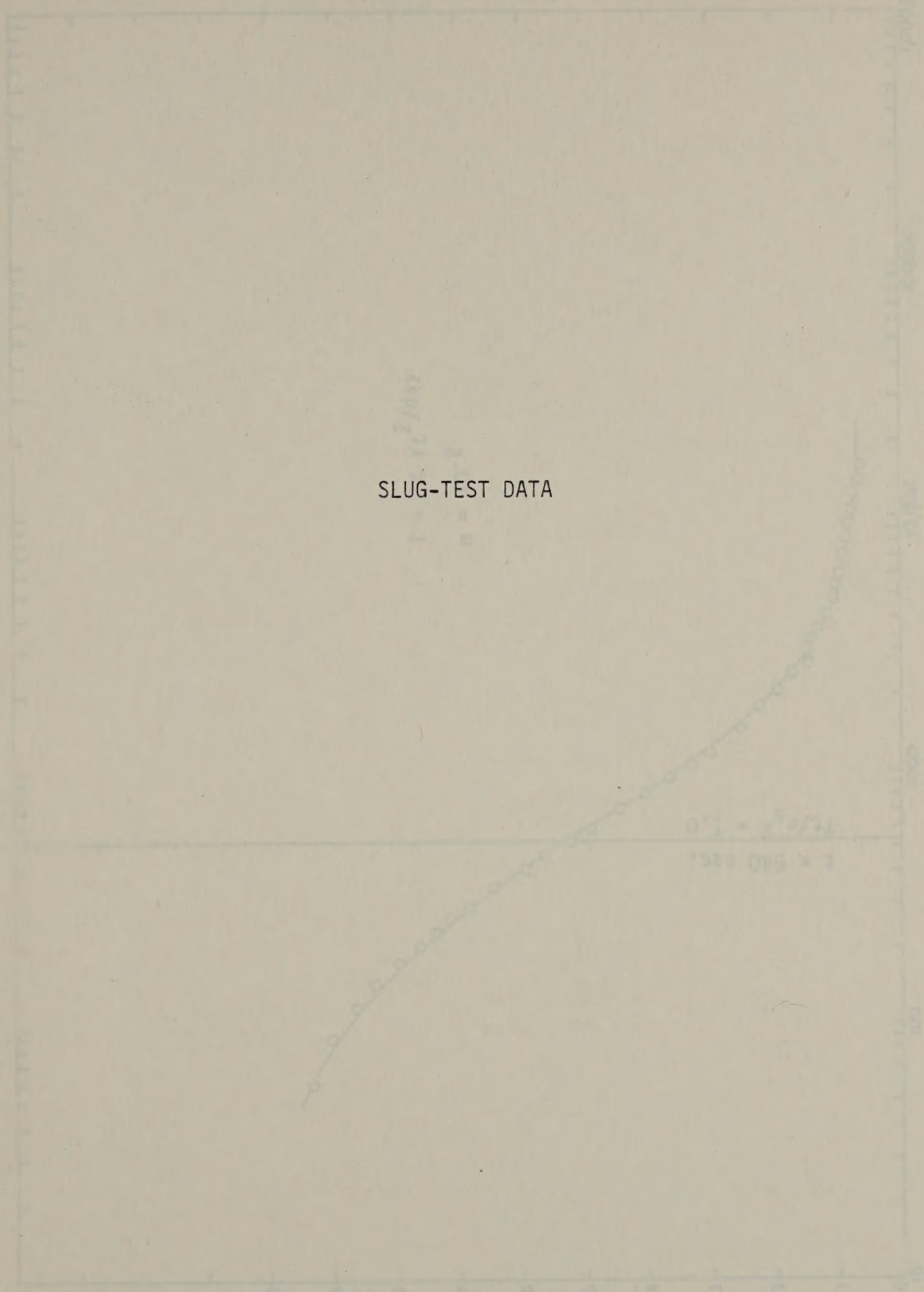
Drawdown and recovery curves.



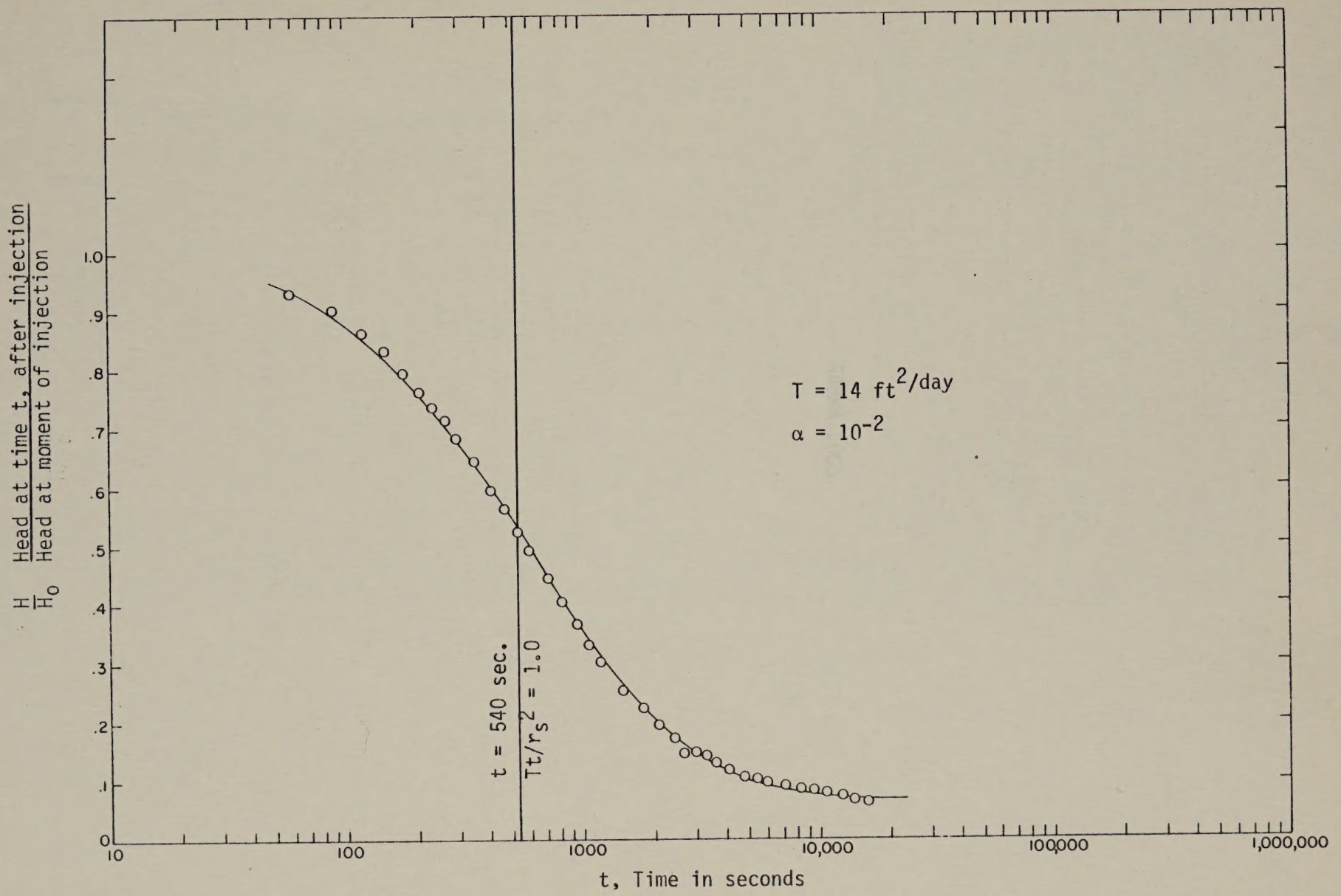
Plot of recovery data for observation well at 21.29.25.423b.



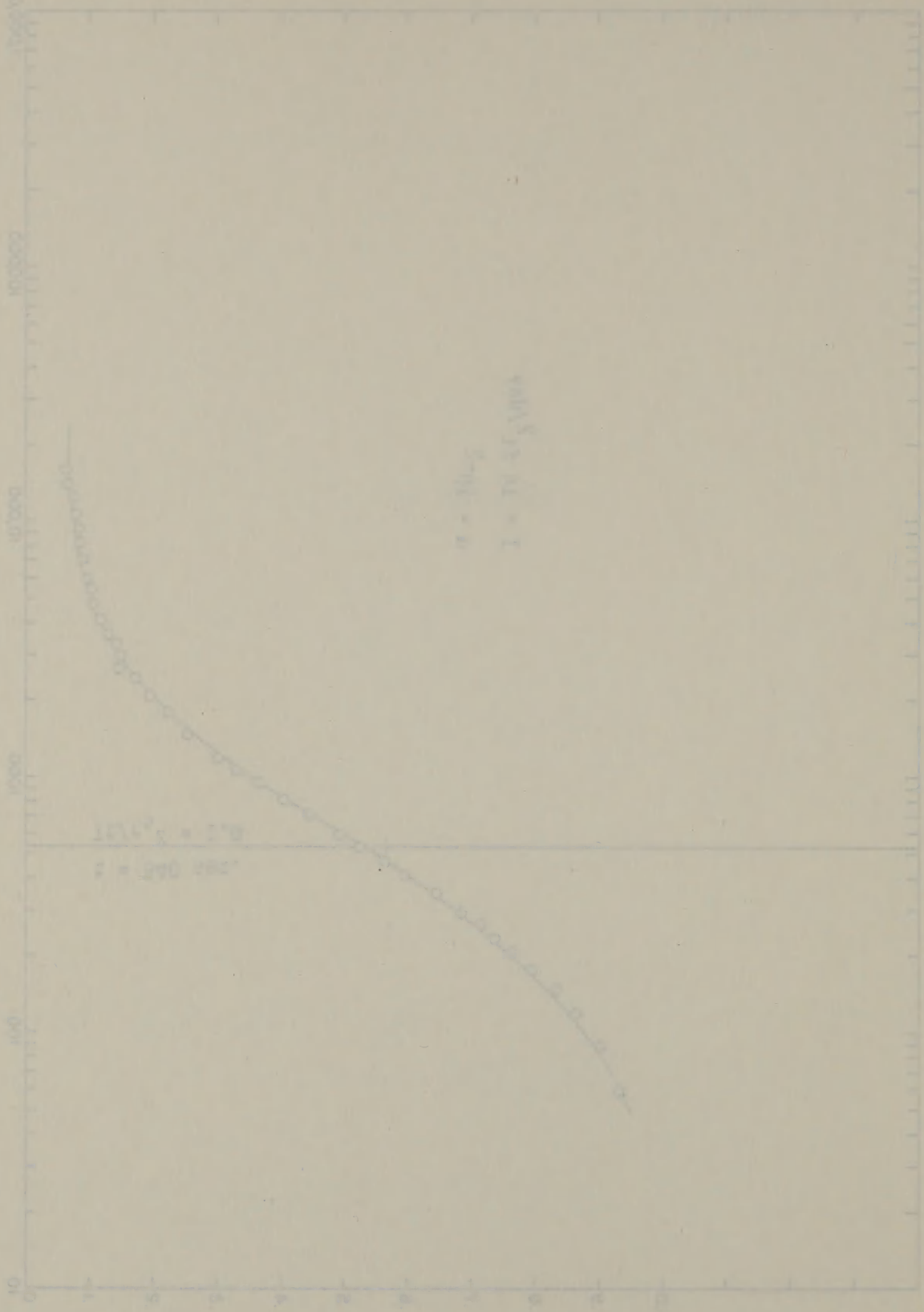
SLUG-TEST DATA



Slug-test data.



Plot of data from slug test on well at 19.30.5.32.



GAMMA LOGS

GAMMA LOGS
(Run by the USGS on BLM Test Holes)

U.S. GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

19.30.3.440

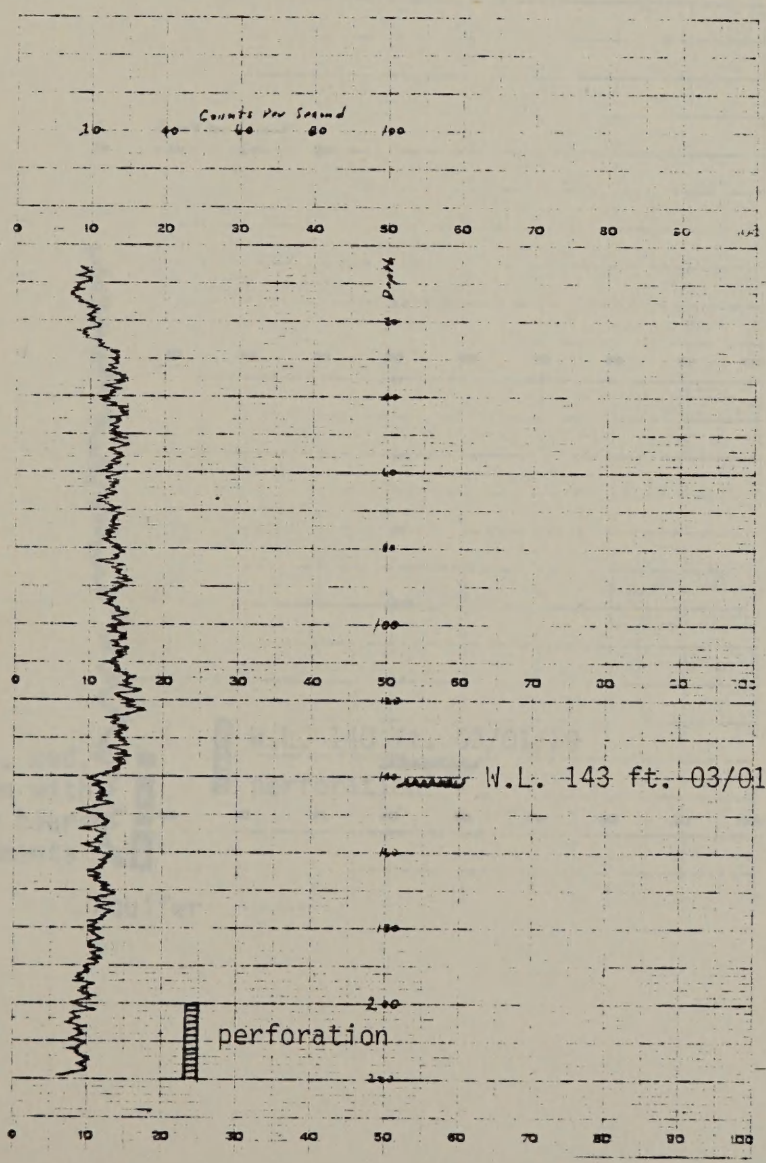
LOG HEADING

LOCATION NO. 19.30.3.440

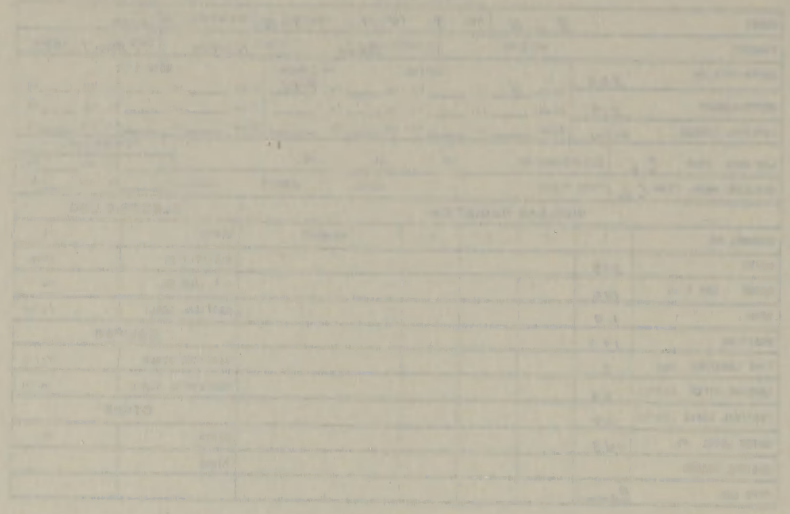
OWNER	B.L.M.	SEC. 3	TWP. 19 S	RNG. 30 E	OPERATOR(S)	Hudson	
PROJECT	HOLE NO.	COUNTY	Eddy	STATE N. Mex.	DATE	Nov 1, 1979	
DEPTH-DRILLER	220	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	219	Diam. 3 in. ___ Ft. to ___ Ft.		P.V.C.	Diam. ___ in. ___ Ft. to ___ Ft.		
INTERVAL LOGGED	Total	Diam. ___ in. ___ Ft. to ___ Ft.			Diam. ___ in. ___ Ft. to ___ Ft.		
LOG MEAS. FROM	G.L.	Diam. ___ in. ___ Ft. to ___ Ft.			Diam. ___ in. ___ Ft. to ___ Ft.		
DRILLERS MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
		TYPE FLUID		LEVEL	DENSITY Lb/Gal	___ Ft. to ___ Ft.	
						___ Ft. to ___ Ft.	

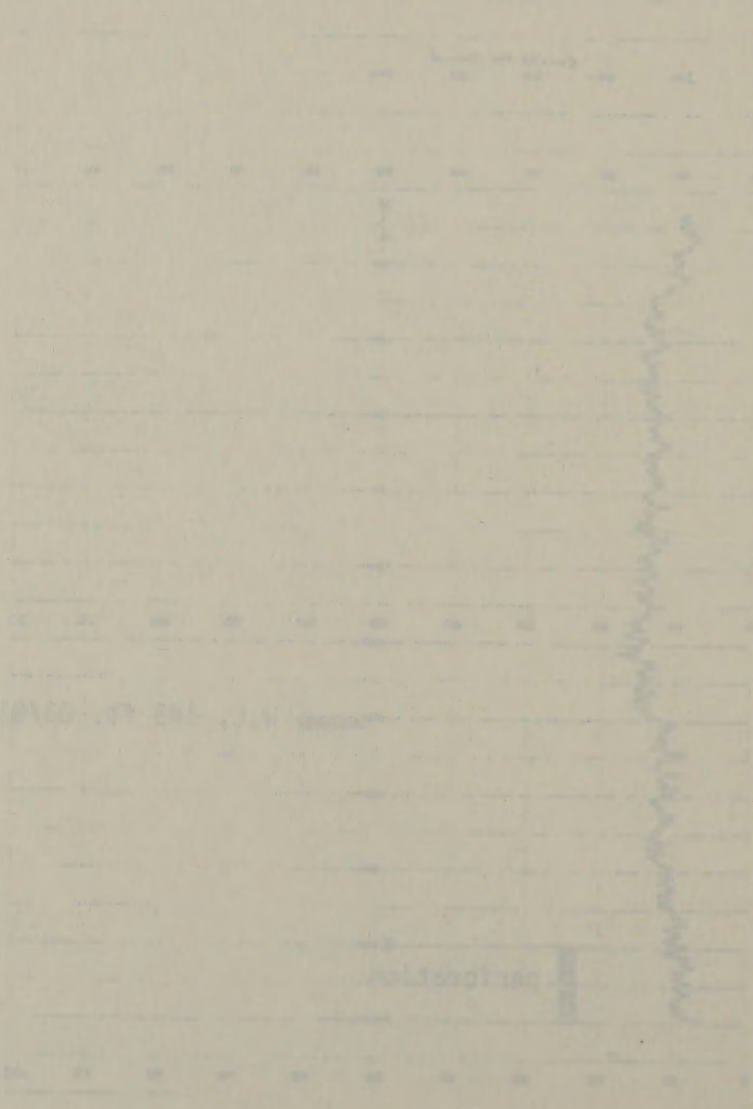
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	219					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	143					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test



~~W.L. 143 ft. 03/01/79~~





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

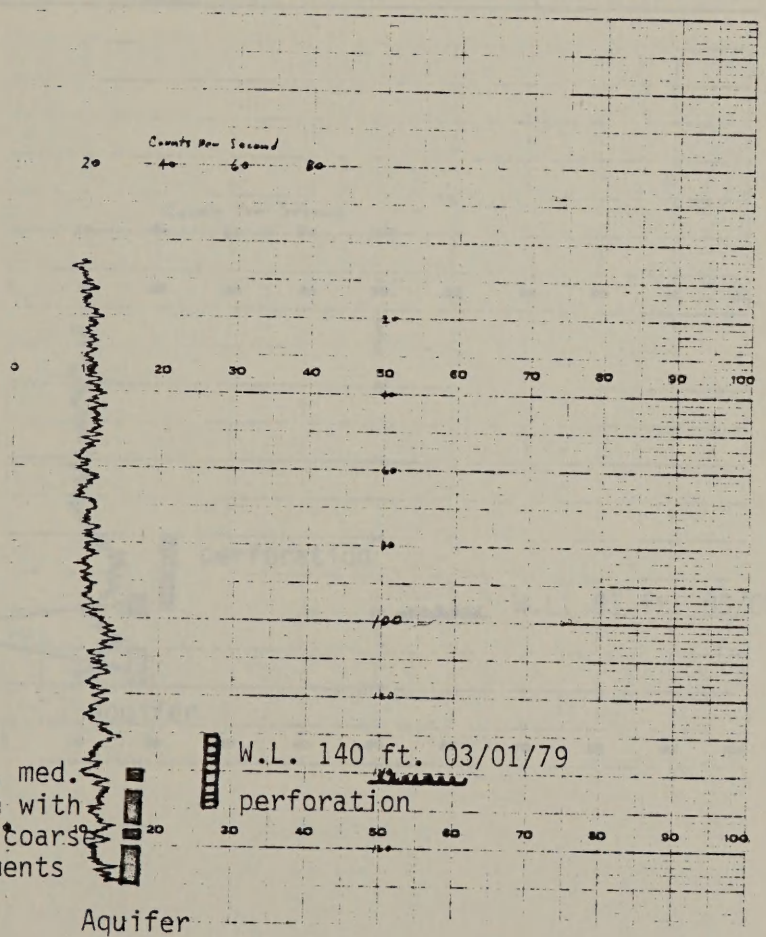
19.30.5.32

LOG HEADING

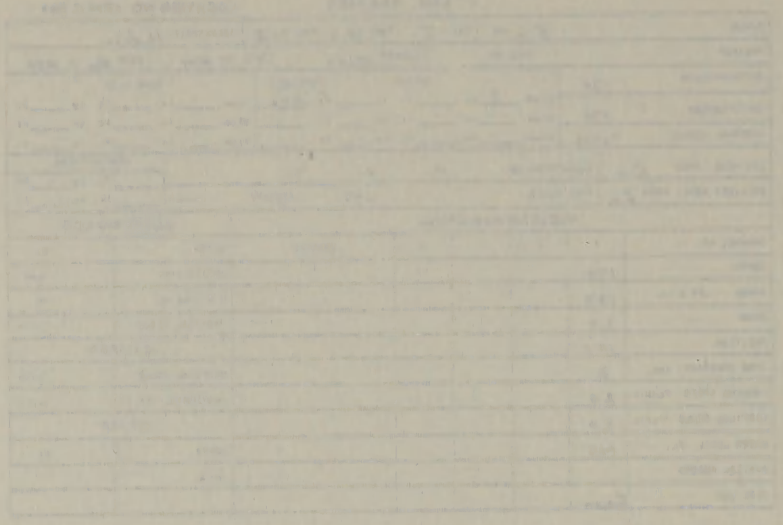
LOCATION NO. 1930.5.32a

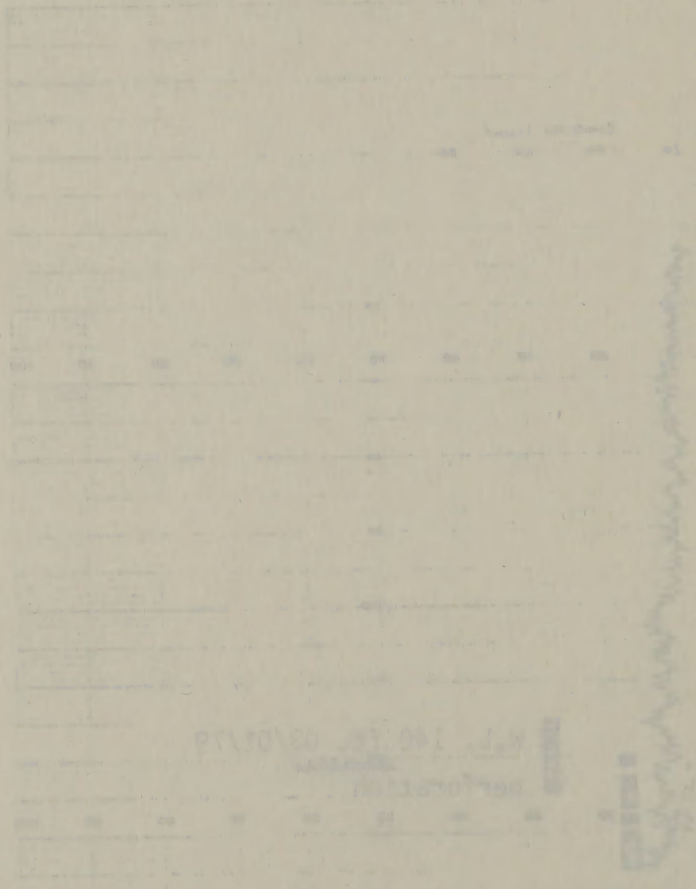
OWNER	B.L.M.	SEC. 5	TWP. 19 S	RNG. 30 E	OPERATOR(S) Hydsom		
PROJECT	HOLE NO.	COUNTY Eddy	STATE N Mex.	DATE Nov. 1, 1979			
DEPTH-DRILLER 170	CASING	THICKNESS	BORE SIZE				
DEPTH-LOGGER 170	Diam. 3 In. ____ Ft. to ____ Ft. P.V.C.		Diam. ____ In. ____ Ft. to ____ Ft.				
INTERVAL LOGGED Total	Diam. ____ In. ____ Ft. to ____ Ft.		Diam. ____ In. ____ Ft. to ____ Ft.				
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS		
DRILLERS MEAS. FROM G.L.	TYPE FLUID	LEVEL	DENSITY Lb/Gal		____ Ft. to ____ Ft.		

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	170					RESISTIVITY	Ohms
RANGE CPS S In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	140					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



Slug Test
Transmissivity
14 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

19.30.35.23

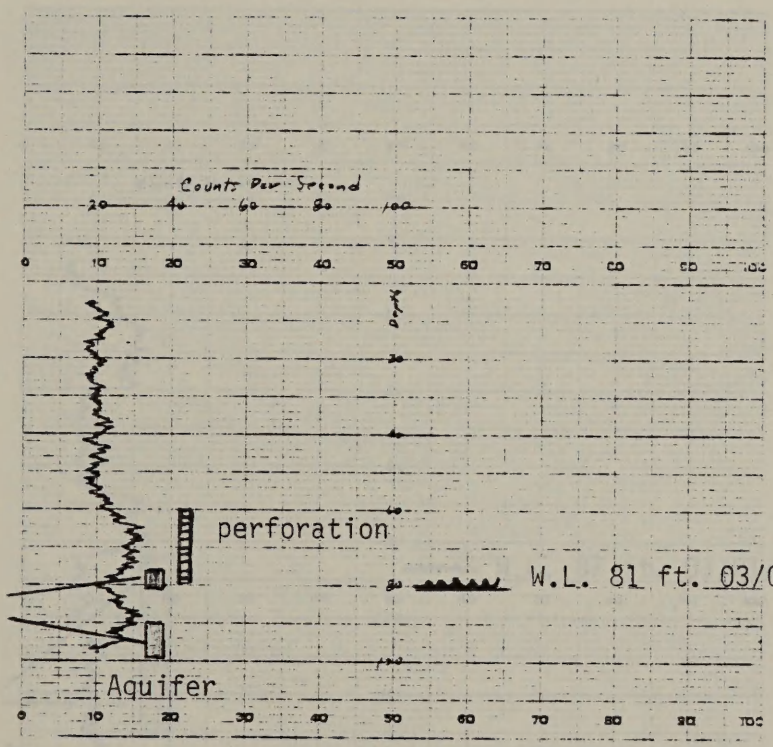
LOG HEADING

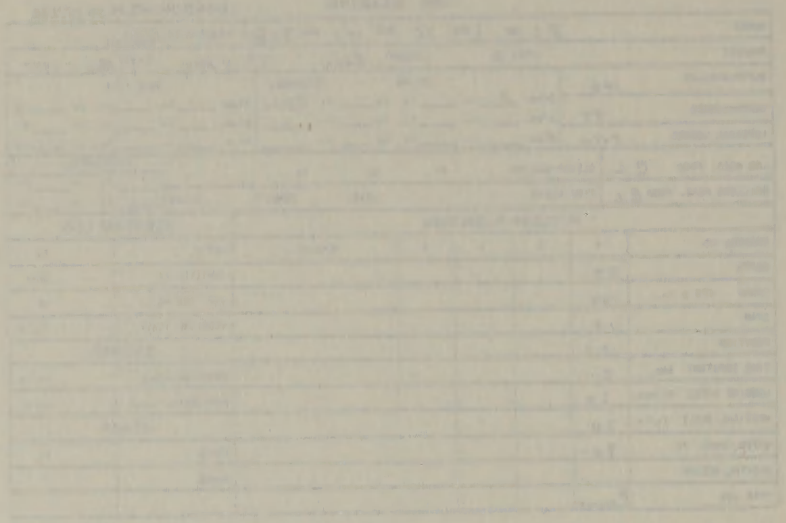
LOCATION NO. 19.30.35.230

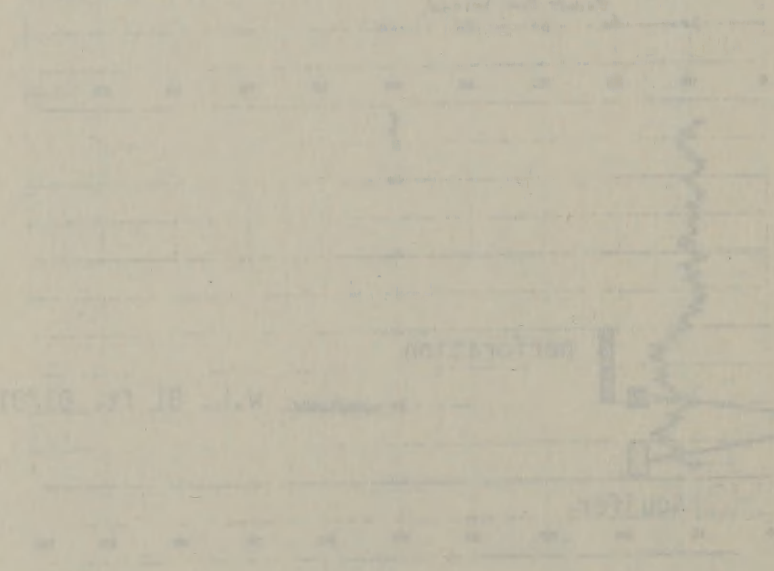
OWNER	B.L.M.	SEC. 35	TWP. 19S	RNG. 30E	OPERATOR(S)	Hudson	
PROJECT	HOLE NO.	COUNTY	Eddy	STATE	N.Mex.	DATE	May 1, 1979
DEPTH-DRILLER	100	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	97	Diam. 3 in. ____ Ft. to ____ Ft.		PVC.	Diam. ____ in. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.			Diam. ____ in. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
DRILLERS MEAS. FROM	G.L.	TYPE FLUID	LEVEL	DENSITY	Lb/Gal	____ Ft. to ____ Ft.	

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	97					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	80					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

Slug Test
Transmissivity
9.4 ft^2/day







Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

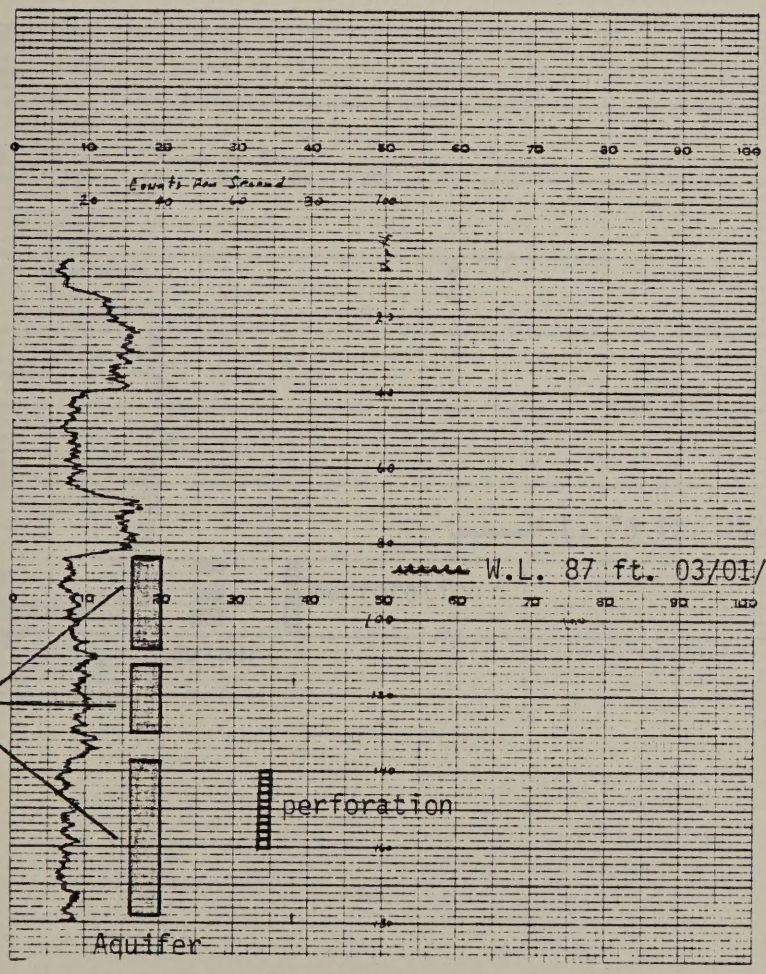
20.29.25.330

LOG HEADING

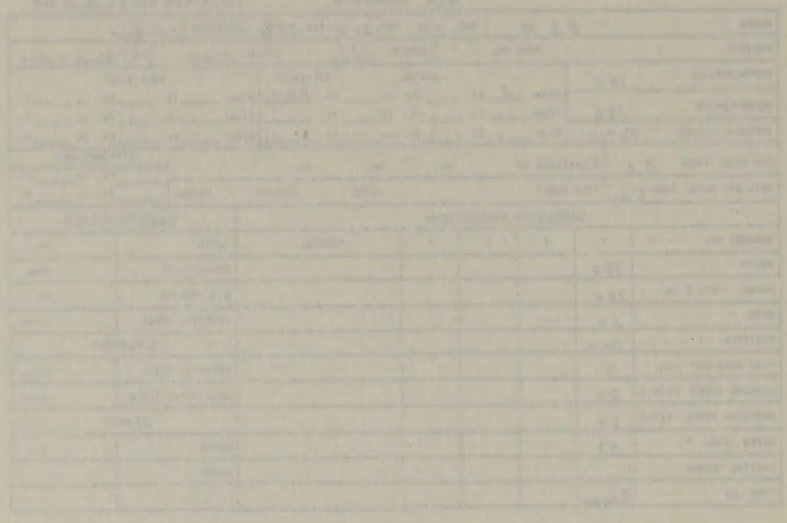
LOCATION NO. 20.29.25.330

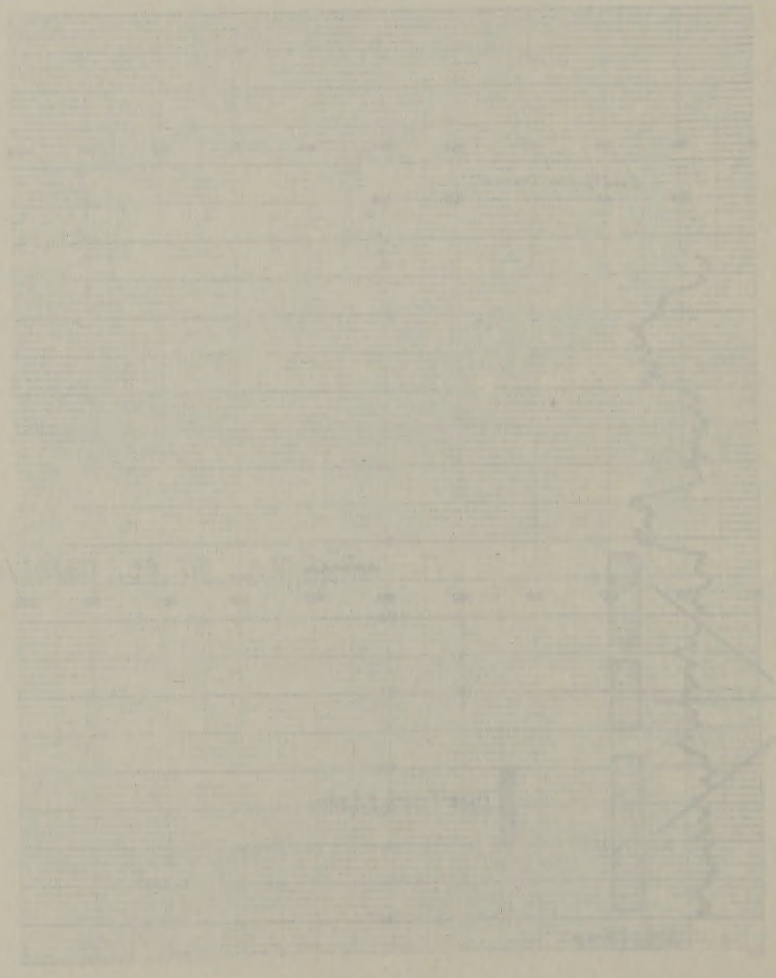
OWNER	B.L.M.	SEC. 25	TWP. 20 S	RNG. 29 E	OPERATOR(S) Hudson
PROJECT	HOLE NO.	COUNTY Eddy	STATE N. Mex.		DATE March 1, 1979
DEPTH-DRILLER	180	CASING	THICKNESS	BORE SIZE	
DEPTH-LOGGER	180	Diam. 3 in. ____ Ft. to ____ Ft.	P.V.C.	Diam. ____ in. ____ Ft. to ____ Ft.	
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.	
		Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.	
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS ____ Ft. to ____ Ft.
DRILLERS MEAS. FROM G.L.	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	180					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	87					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



Slug Test
Transmissivity
330 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.30.23.11

LOG HEADING

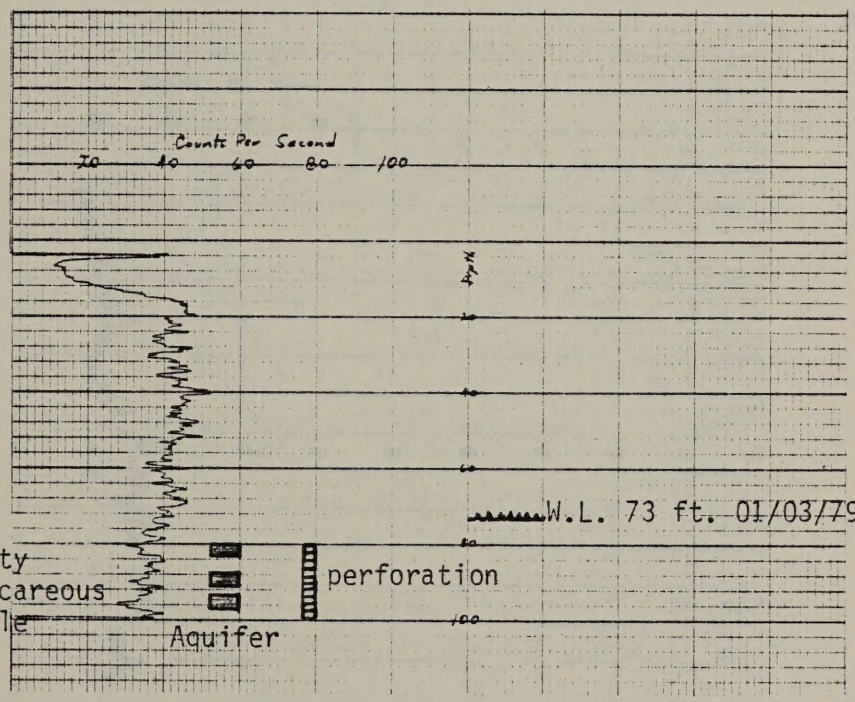
LOCATION NO. 20.30.23.110

OWNER	B.L.M.	SEC. 23	TWP. 20s	RNG. 30w	OPERATOR(S)	Cruz	
PROJECT	HOLE NO.	COUNTY	Eddy	STATE	N.Mex.	DATE	May 1, 1979

	CASING	THICKNESS	BORE SIZE
DEPTH-DRILLER 100	Diam. 3 In. ____ Ft. to ____ Ft.	P.V.C.	Diam. ____ In. ____ Ft. to ____ Ft.
DEPTH-LOGGER 100	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.
INTERVAL LOGGED Total	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.

LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.		PERFORATIONS
DRILLERS MEAS. FROM G.L.	TYPE FLUID		LEVEL	DENSITY	Lb/Gal	____ Ft. to ____ Ft.
						____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	100					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	73					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



Aquifer Test
Transmissivity
12 ft^2/day

Gamma logs, continued.

U.S. GEOLOGICAL SURVEY

WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.30.25.33

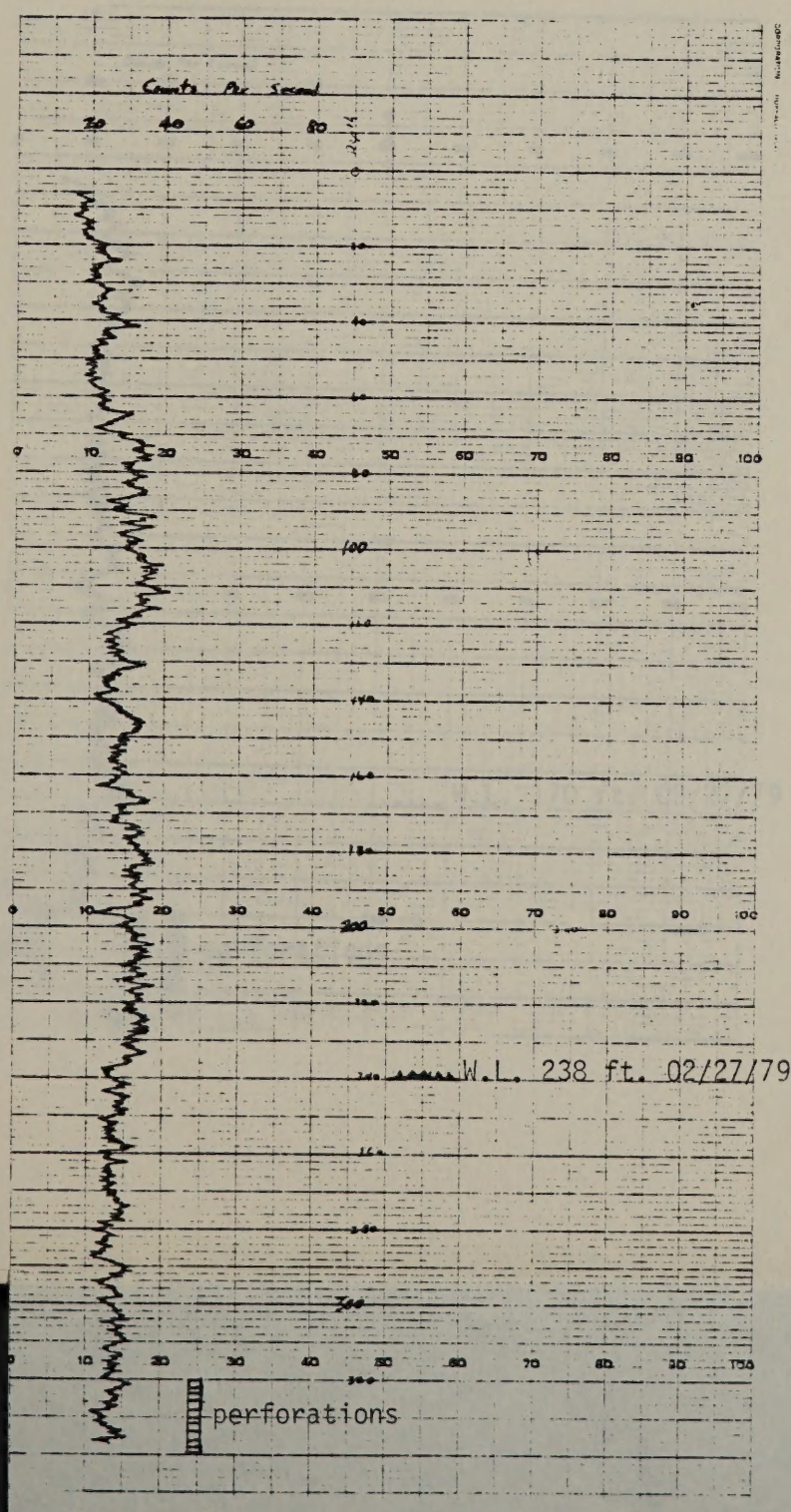
LOG HEADING

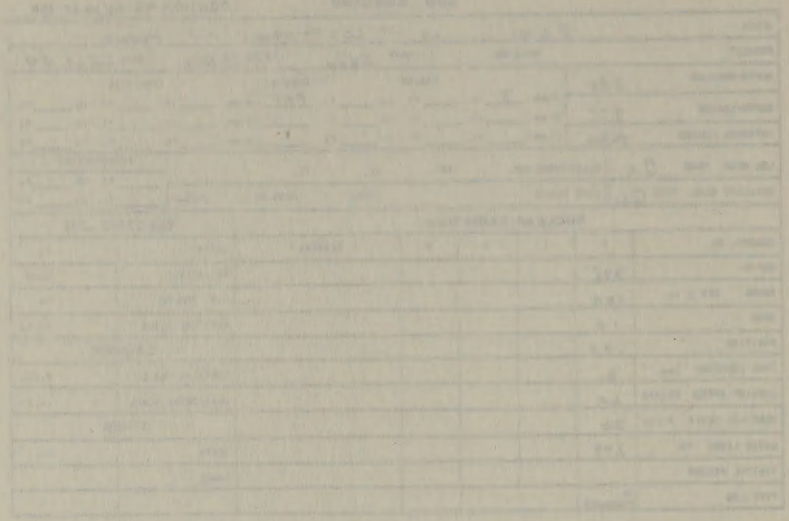
LOCATION NO. 20.30.25.330

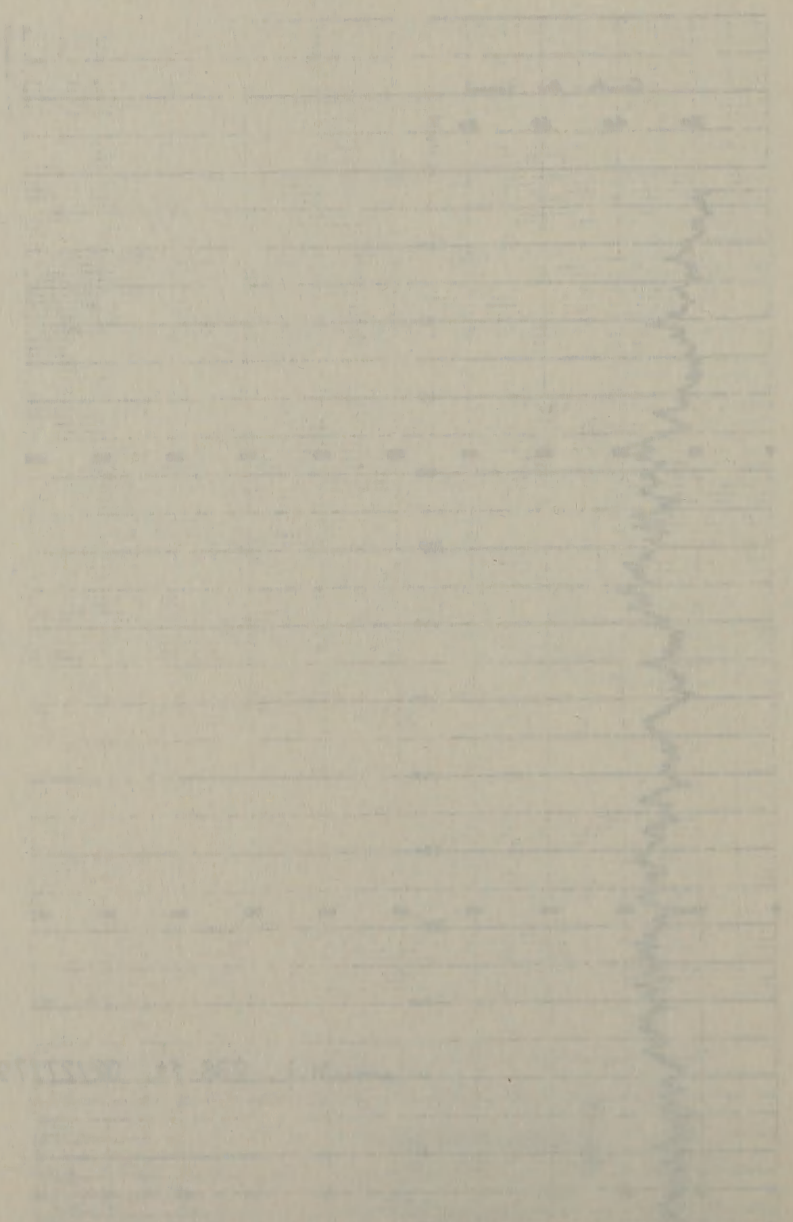
OWNER	B.L.M.				
PROJECT	HOLE NO.	COUNTY Eddy	STATE N.Mex.	DATE Feb 27, 1979	
DEPTH-DRILLER 340	CASING	THICKNESS	BORE SIZE		
DEPTH-LOGGER 335	Diam. 3 in. ____ Ft. to ____ Ft.	PVC	Diam. ____ in. ____ Ft. to ____ Ft.		
INTERVAL LOGGED Total	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.		
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS
DRILLERS MEAS. FROM G.L.	TYPE FLUID	LEVEL	DENSITY Lb/Gal		____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	335					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	10					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	238					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test







Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

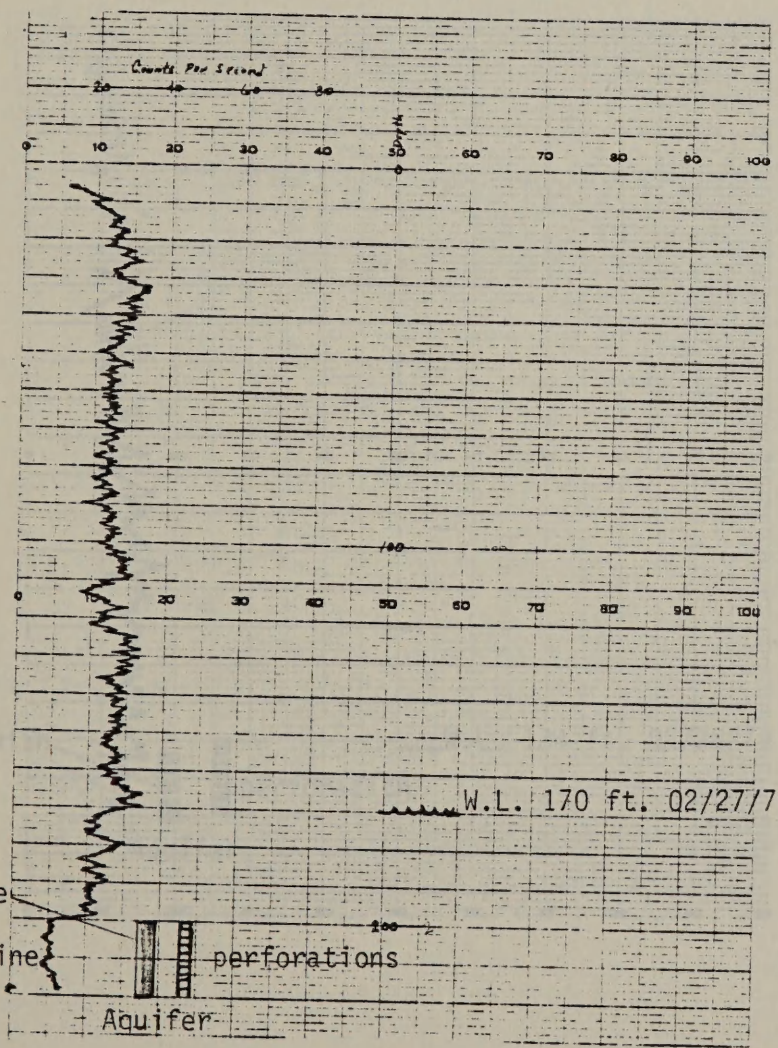
20.30.28.44

LOG HEADING

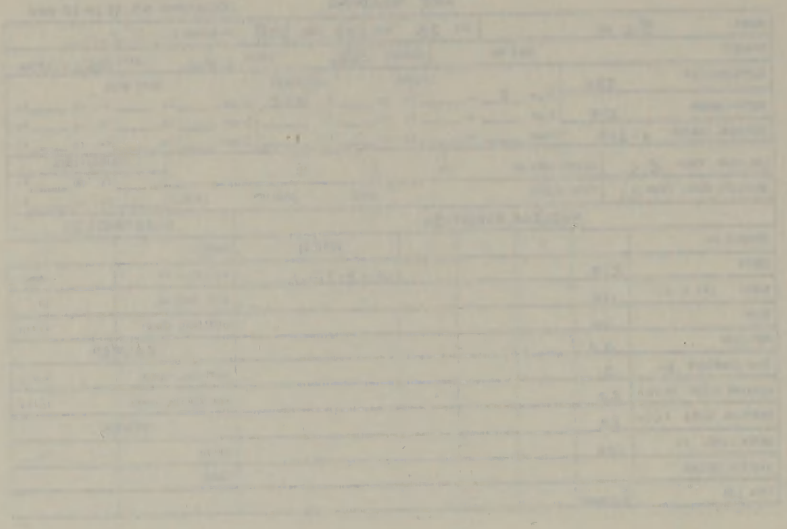
LOCATION NO. 29 20.28.440

OWNER	B.L.M.	SEC. 28	TWP. 20S	RNG. 29E	OPERATOR(S)	Cruz	
PROJECT	HOLE NO.	COUNTY	Eddy	STATE	N. Mex.	DATE	Feb. 27, 1979
DEPTH-DRILLER	220	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	219	Diam. 3 in. ____ Ft. to ____ Ft.		P.V.C.	Diam. ____ in. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	6-219	Diam. ____ in. ____ Ft. to ____ Ft.			Diam. ____ in. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	Diam. ____ in. ____ Ft. to ____ Ft.			Diam. ____ in. ____ Ft. to ____ Ft.		
DRILLERS MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
		TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.	
						____ Ft. to ____ Ft.	

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	219				20 C.P.S./inch	RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	100					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	170					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



Slug Test
Transmissivity
0.06 ft^2/day



Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

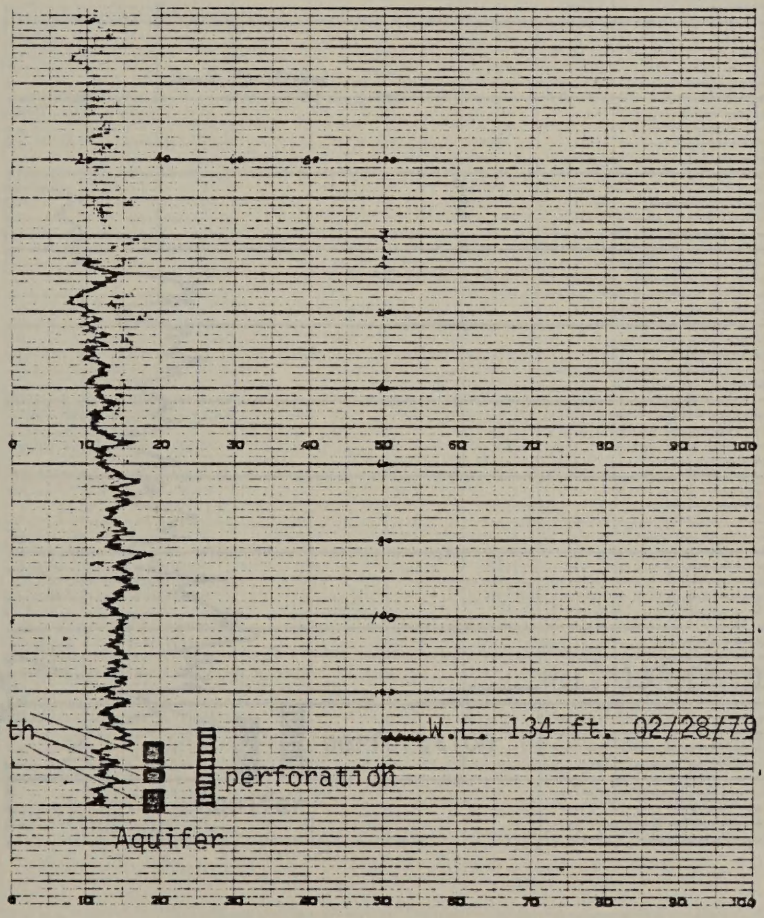
20.30.29.33

LOG HEADING

LOCATION NO. 20.30.29.330

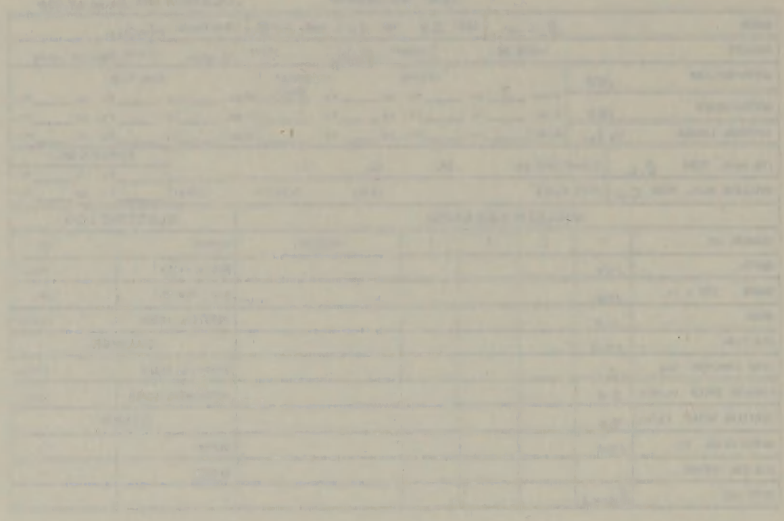
OWNER	B.L.M.	SEC. 29	TWP. 20 S	RNG. 30 E	OPERATOR(S)	Hudson	
PROJECT		HOLE NO.	COUNTY	Eddy	STATE	N.Mex.	DATE Feb. 28, 1979
DEPTH-DRILLER	150	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	150	Diam. 3 in. ____ Ft. to ____ Ft.		P.V.C.	Diam. ____ in. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.		____	Diam. ____ in. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
DRILLERS MEAS. FROM	G.L.	TYPE FLUID	LEVEL	DENSITY	Lb/Gal	____ Ft. to ____ Ft.	

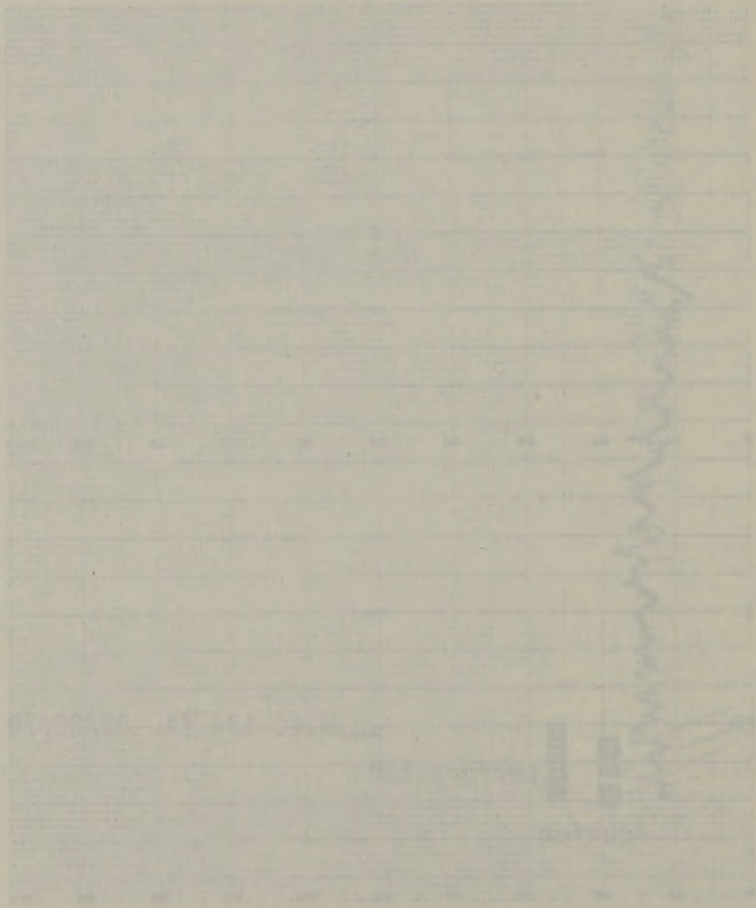
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	150					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/in
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/in
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/in
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	134					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



silty shale with gypsum

Slug Test
Transmissivity
3.0 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.31.2.34

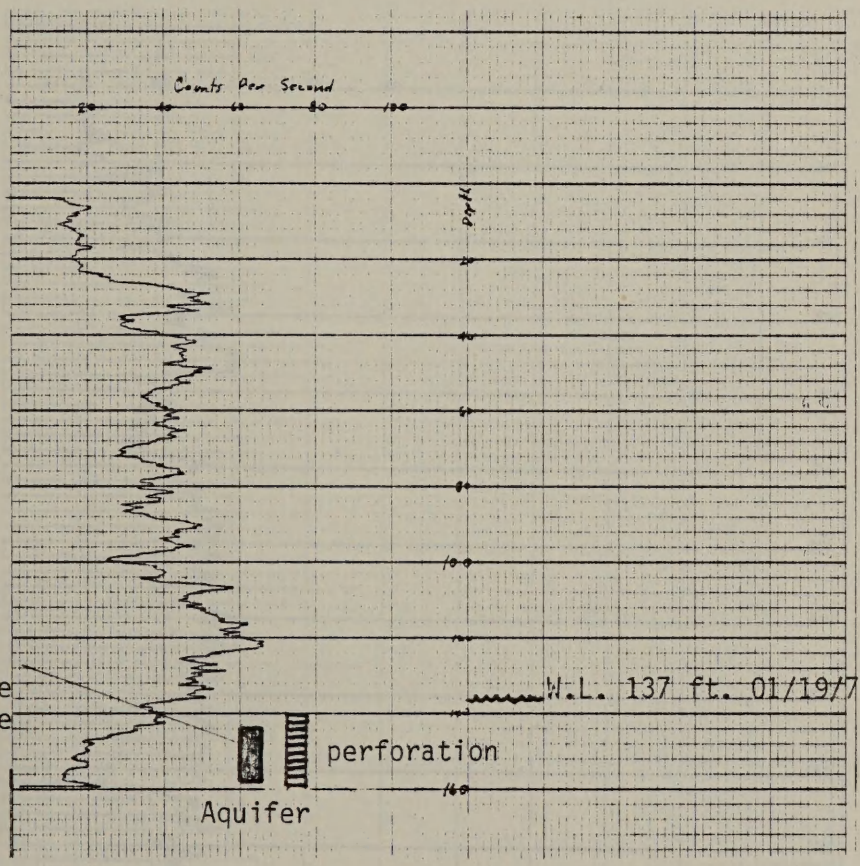
LOG HEADING

LOCATION NO. 20.31.3.140

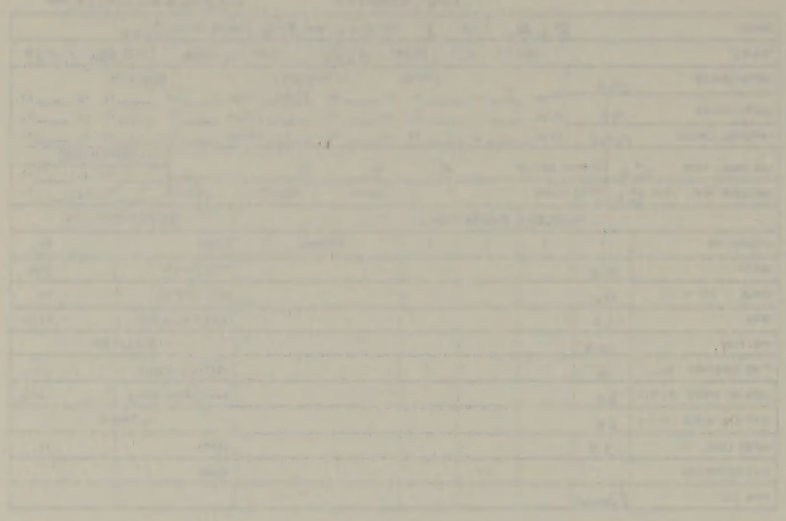
OWNER	B.L.M.	SEC. 3	TWP. 20S	RNG. 31E	OPERATOR(S)	Cruz	
PROJECT		HOLE NO. 2	COUNTY Eddy	STATE N. Mex.	DATE	Nov. 1, 1979	
DEPTH-DRILLER	160	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	160	Diam. 3 In. ____ Ft. to ____ Ft.		P.V.C.	Diam. ____ In. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	Total	Diam. ____ In. ____ Ft. to ____ Ft.			Diam. ____ In. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
DRILLERS MEAS. FROM	G.L.	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.	

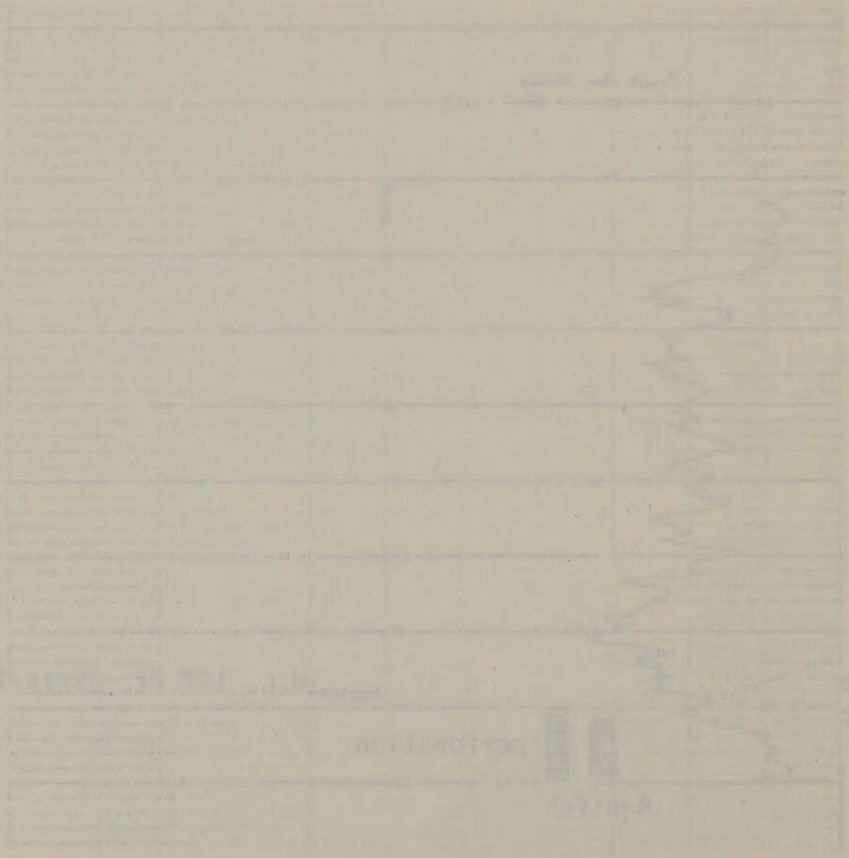
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	160					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	137					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

Slug Test
Transmissivity
0.97 ft^2/day



sandstone
med.-fine
grained
calcite
cement





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

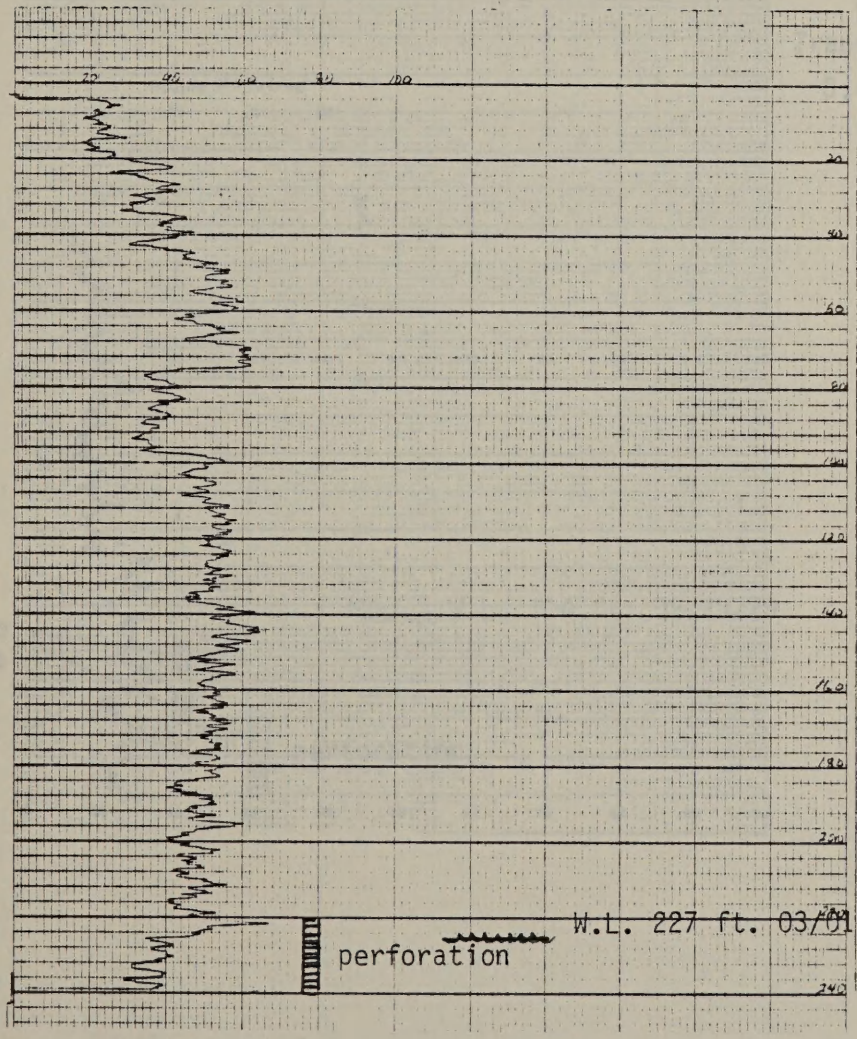
20.31.17.33

LOG HEADING

LOCATION NO. 205. 31E 17.33

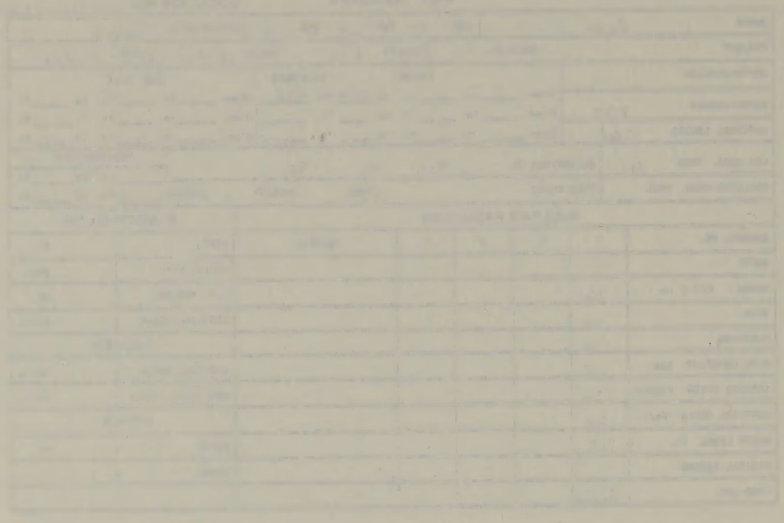
OWNER	BLM			SEC. 17	TWP. 20S	RNG. 31E	OPERATOR(S)	CWC		
PROJECT		HOLE NO.		COUNTY Lea		STATE N Mex.	DATE 3/1/79			
DEPTH-DRILLER		CASING			THICKNESS		BORE SIZE			
DEPTH-LOGGER	239	Diam. 3 in.	2 Ft. to 234 Ft.		PVC		Diam. ____ in.	____ Ft. to ____ Ft.		
		Diam. ____ in.	____ Ft. to ____ Ft.		____		Diam. ____ in.	____ Ft. to ____ Ft.		
INTERVAL LOGGED	Tabl	Diam. ____ in.	____ Ft. to ____ Ft.		____		Diam. ____ in.	____ Ft. to ____ Ft.		
LOG MEAS. FROM	GL	ELEVATIONS KB.	DF.	GL.	TC.		PERFORATIONS			
DRILLERS MEAS. FROM		TYPE FLUID		LEVEL	DENSITY	Lb/Gal	____ Ft. to ____ Ft.			
							____ Ft. to ____ Ft.			

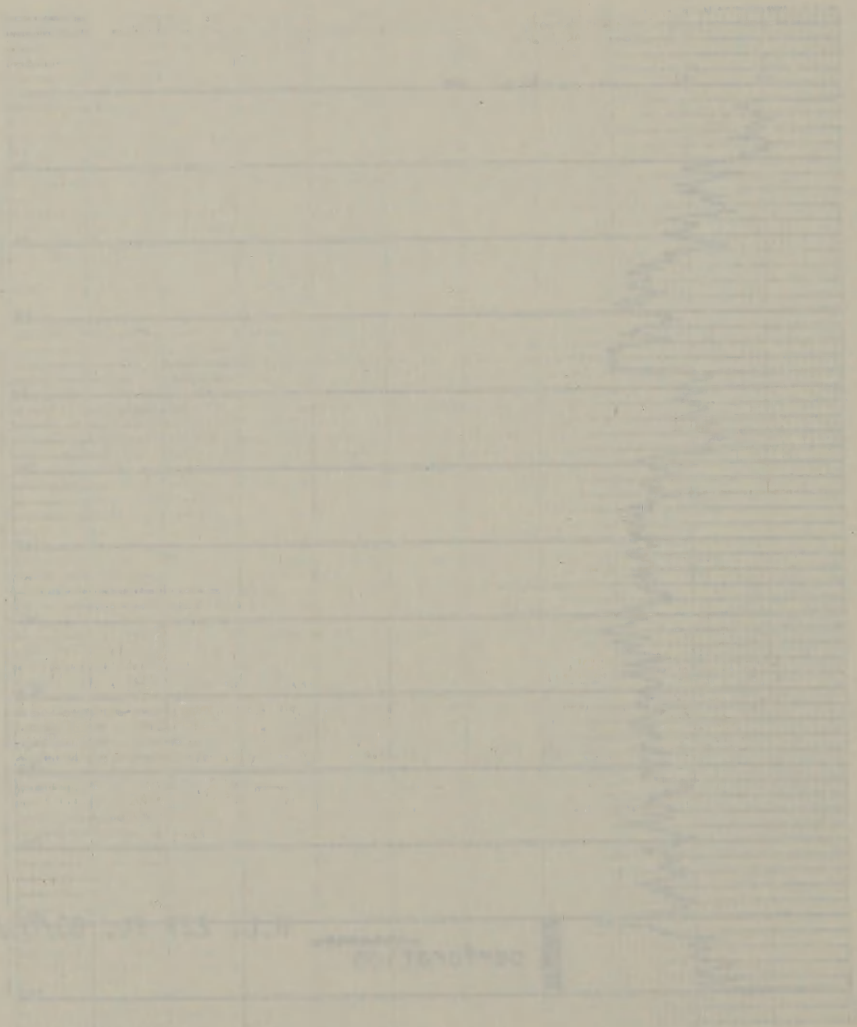
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH						RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	10					VERTICAL SCALE	Ft/In
POSITION	10					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	227					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



No Test

W.L. 227 ft. 03/01/79





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.31.27.240

LOG HEADING

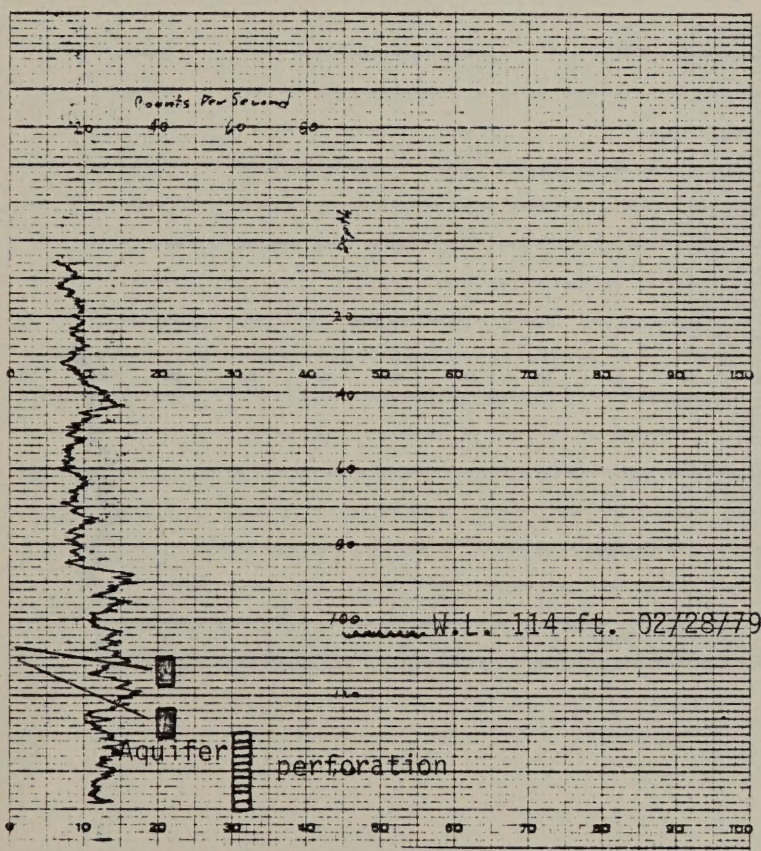
LOCATION NO. 20.31.27.240

OWNER	B.L.M.	SEC. 27	TWP. 20 S	RNG. 31 E	OPERATOR(S)	Hudson	
PROJECT		HOLE NO.	COUNTY	Lea	STATE	N. Mex.	DATE Feb 28, 1979

		CASING	THICKNESS	BORE SIZE
DEPTH-DRILLER	150	Diam. 3 in. ____ Ft. to ____ Ft.	P.V.C.	Diam. ____ in. ____ Ft. to ____ Ft.
DEPTH-LOGGER	149	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.

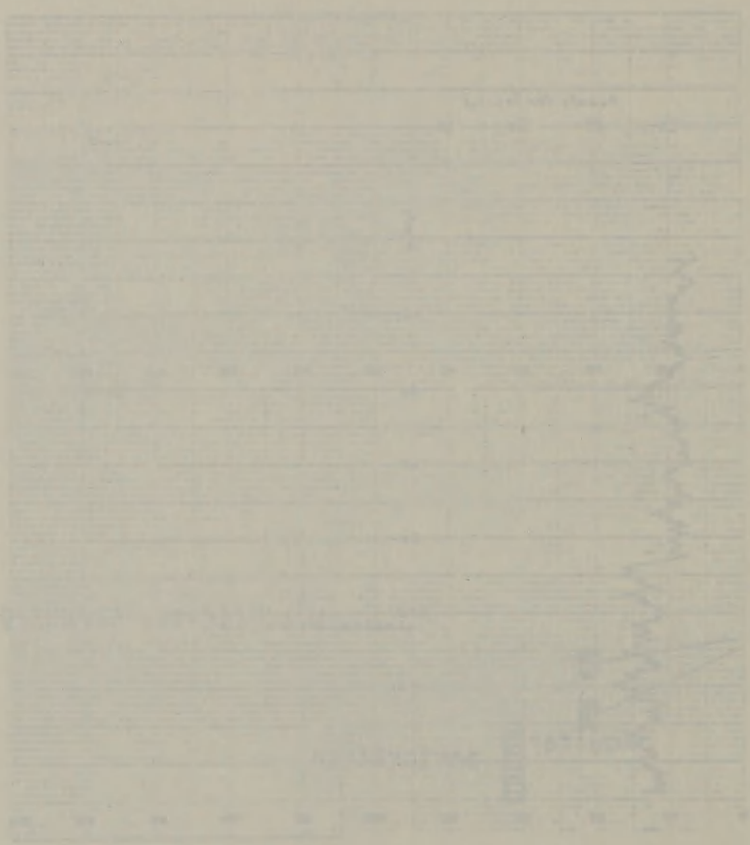
LOG MEAS. FROM	T.C.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS ____ Ft. to ____ Ft.
DRILLERS MEAS. FROM	C.L.	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	149					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	114					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



siltstone stringers

Slug Test
Transmissivity
0.44 ft^2/day



Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.31.30.440

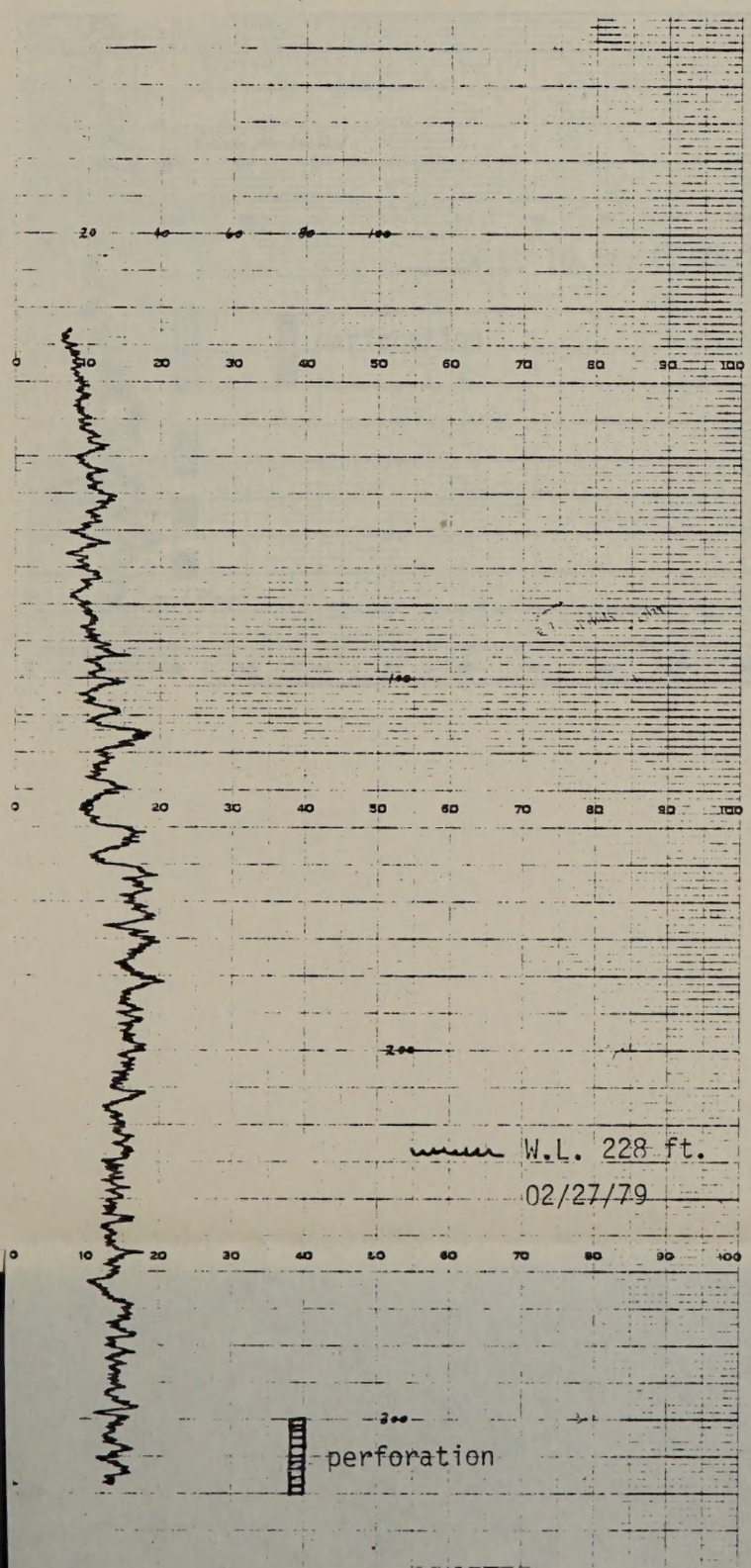
LOG HEADING

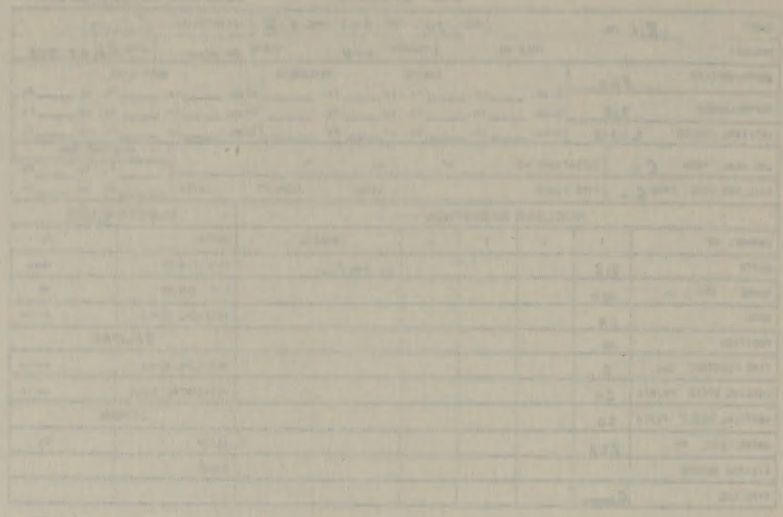
LOCATION NO. 20.31.30.440

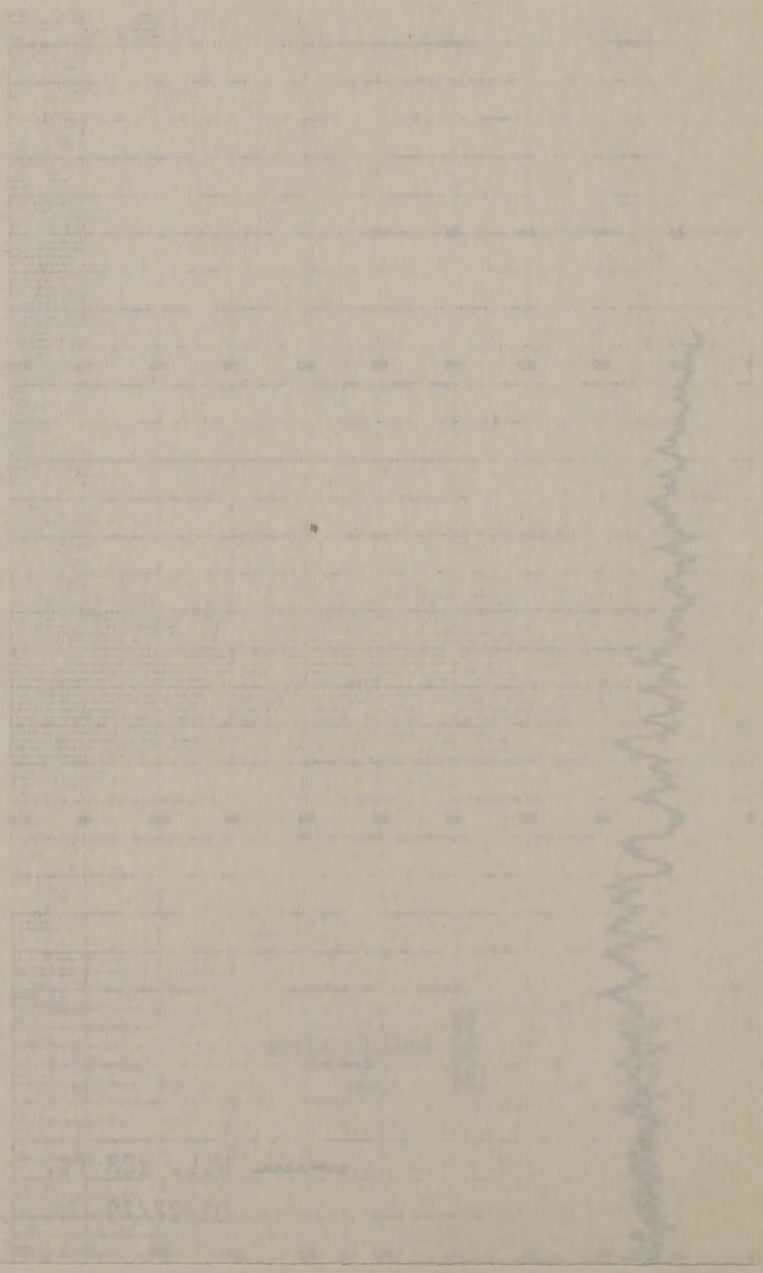
OWNER	B.L.M.			SEC. 30	TWP. 20S	RNG. 31E	OPERATOR(S)	Cuniz	
PROJECT		HOLE NO.		COUNTY Lea		STATE N. Mex.	DATE Feb. 27, 1979		
DEPTH-DRILLER	320	CASING			THICKNESS	BORE SIZE			
DEPTH-LOGGER	318	Diam. ___ In. ___ Ft. to ___ Ft. ___				Diam. ___ In. ___ Ft. to ___ Ft.			
INTERVAL LOGGED	6-318	Diam. ___ In. ___ Ft. to ___ Ft. ___				Diam. ___ In. ___ Ft. to ___ Ft.			
		Diam. ___ In. ___ Ft. to ___ Ft. ___				Diam. ___ In. ___ Ft. to ___ Ft.			
LOG MEAS. FROM	G.L.	ELEVATIONS KB.		DF.	GL.	TC.	PERFORATIONS		
DRILLERS MEAS. FROM	G.L.	TYPE FLUID			LEVEL	DENSITY Lb/Gal	___ Ft. to ___ Ft.		
							___ Ft. to ___ Ft.		

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft
DEPTH	318				20 CPS/in	RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	228					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test







.Gamma logs, continued.

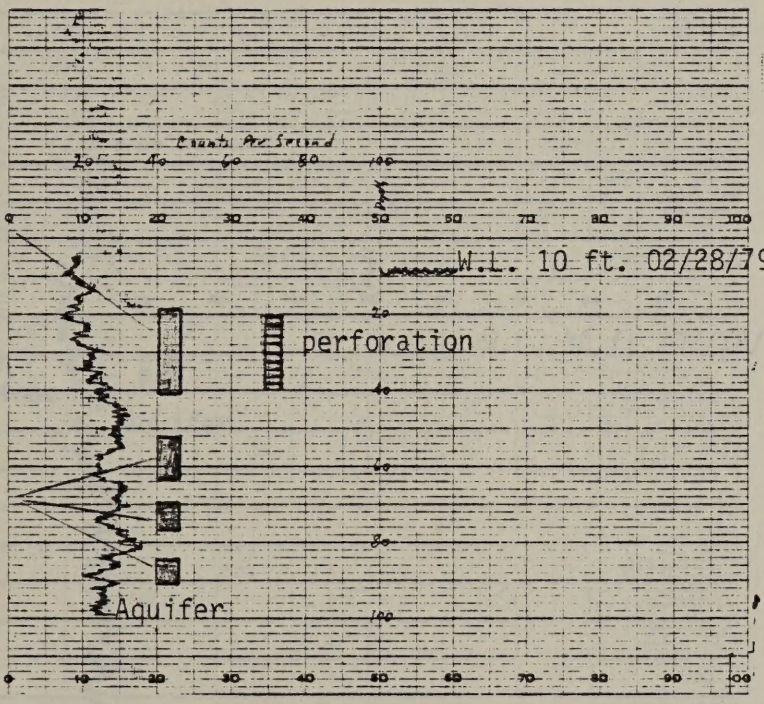
U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.32.17.13

LOG HEADING LOCATION NO. 20.32.17.130

OWNER	B.L.M.	SEC. 17	TWP. 20 S	RNG. 32 E	OPERATOR(S) Hudson		
PROJECT		HOLE NO.	COUNTY Lea	STATE N. Mex.	DATE Feb 23, 1979		
DEPTH-DRILLER	100	CASING		THICKNESS	BORE SIZE		
DEPTH-LOGGER	100	Diam. 3 In. ____ Ft. to ____ Ft.		PVC	Diam. ____ In. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	Total	Diam. ____ In. ____ Ft. to ____ Ft.			Diam. ____ In. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
DRILLERS MEAS. FROM	G.L.	TYPE FLUID	LEVEL	DENSITY	Lb/Gal	____ Ft. to ____ Ft.	

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	100					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	9					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



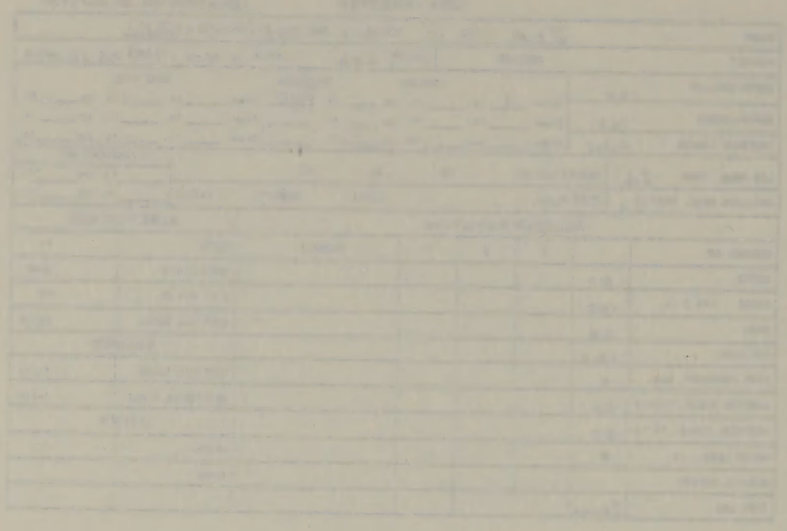
sandstone and sandy shale

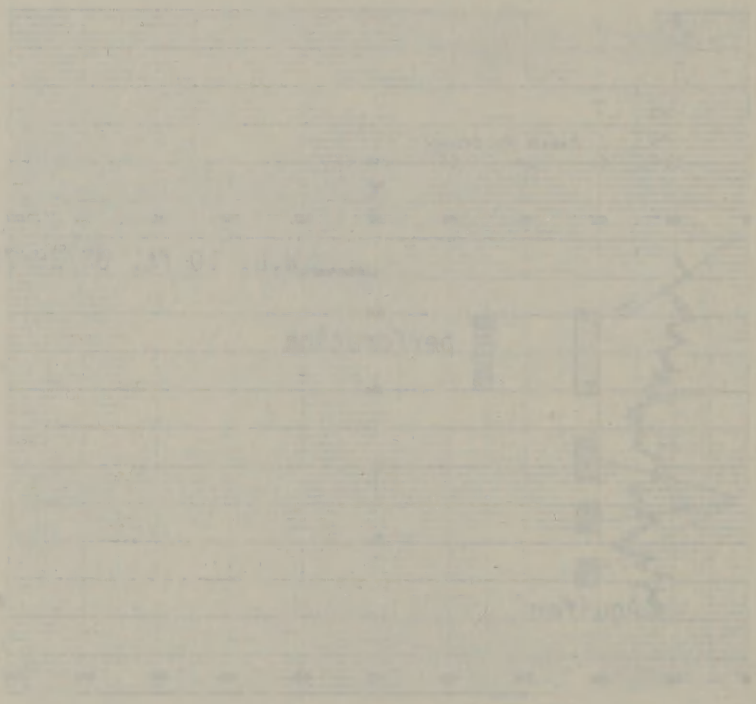
silty shale

Aquifer Test

Transmissivity

350 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

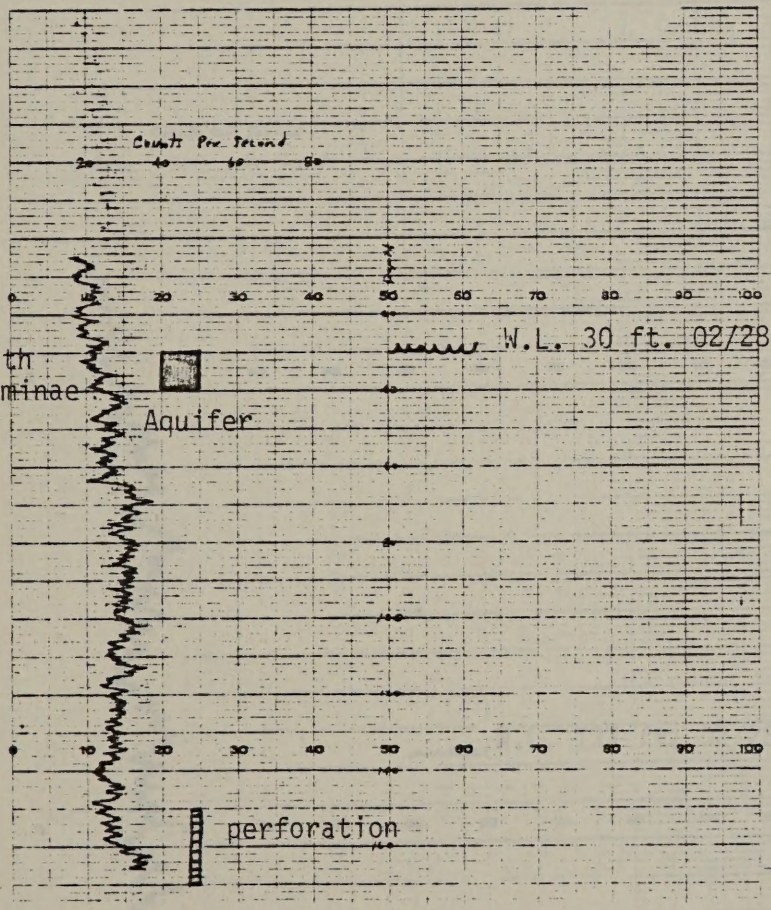
20.32.22.33

LOG READING

LOCATION NO. 20.32.22.230

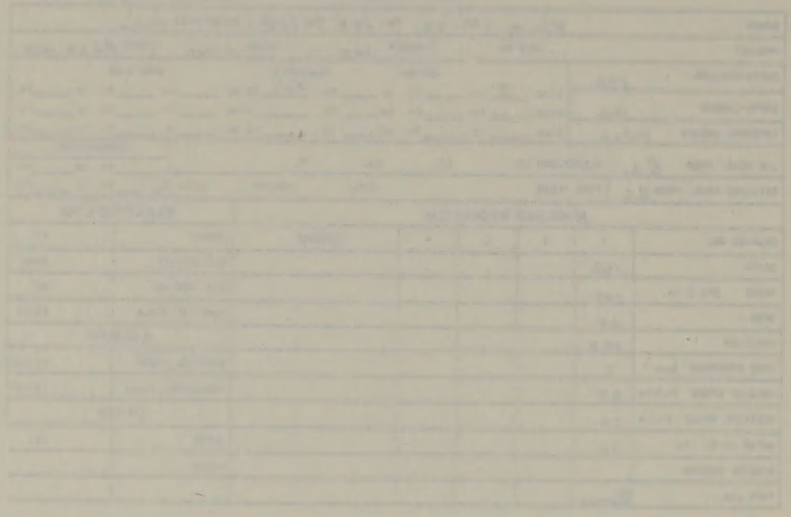
OWNER	B.L.M.	SEC. 28	TWP. 20S	RNG. 32E	OPERATOR(S) Hudson		
PROJECT		HOLE NO.	COUNTY Lea	STATE N. Mex.	DATE Feb 28, 1979		
DEPTH-DRILLER	170	CASING		THICKNESS	BORE SIZE		
		Diam. 3 in. ____ Ft. to ____ Ft.		P.V.C.	Diam. ____ in. ____ Ft. to ____ Ft.		
DEPTH-LOGGER	166	Diam. ____ in. ____ Ft. to ____ Ft.			Diam. ____ in. ____ Ft. to ____ Ft.		
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.			Diam. ____ in. ____ Ft. to ____ Ft.		
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS	
DRILLERS MEAS. FROM	G.L.	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.	
						____ Ft. to ____ Ft.	

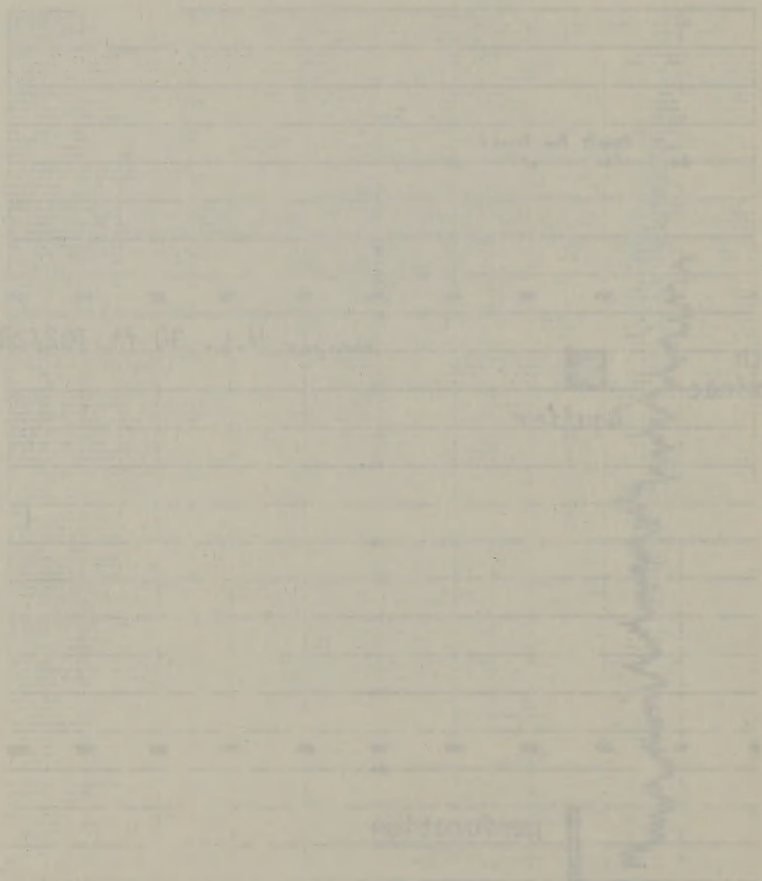
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	166					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	30					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



Aquifer Test

Transmissivity
5 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

20.32.31.13

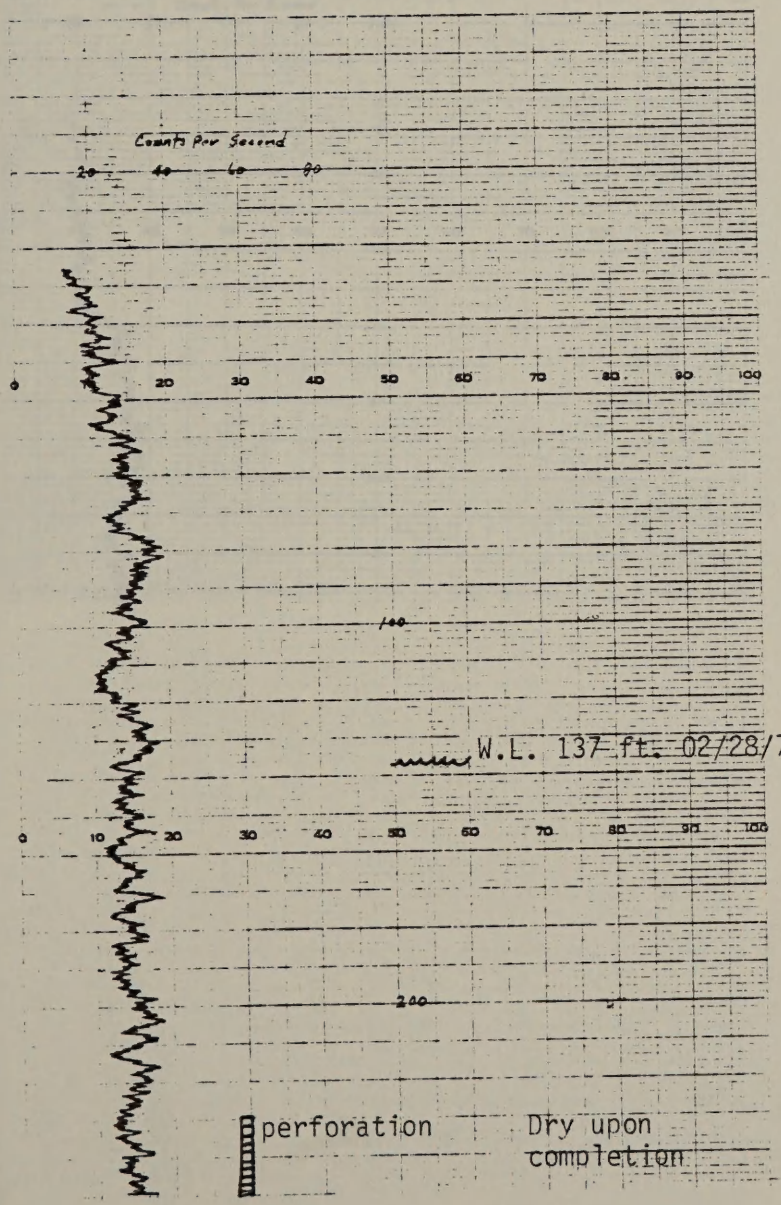
LOG HEADING LOCATION NO. 20.32.31.130

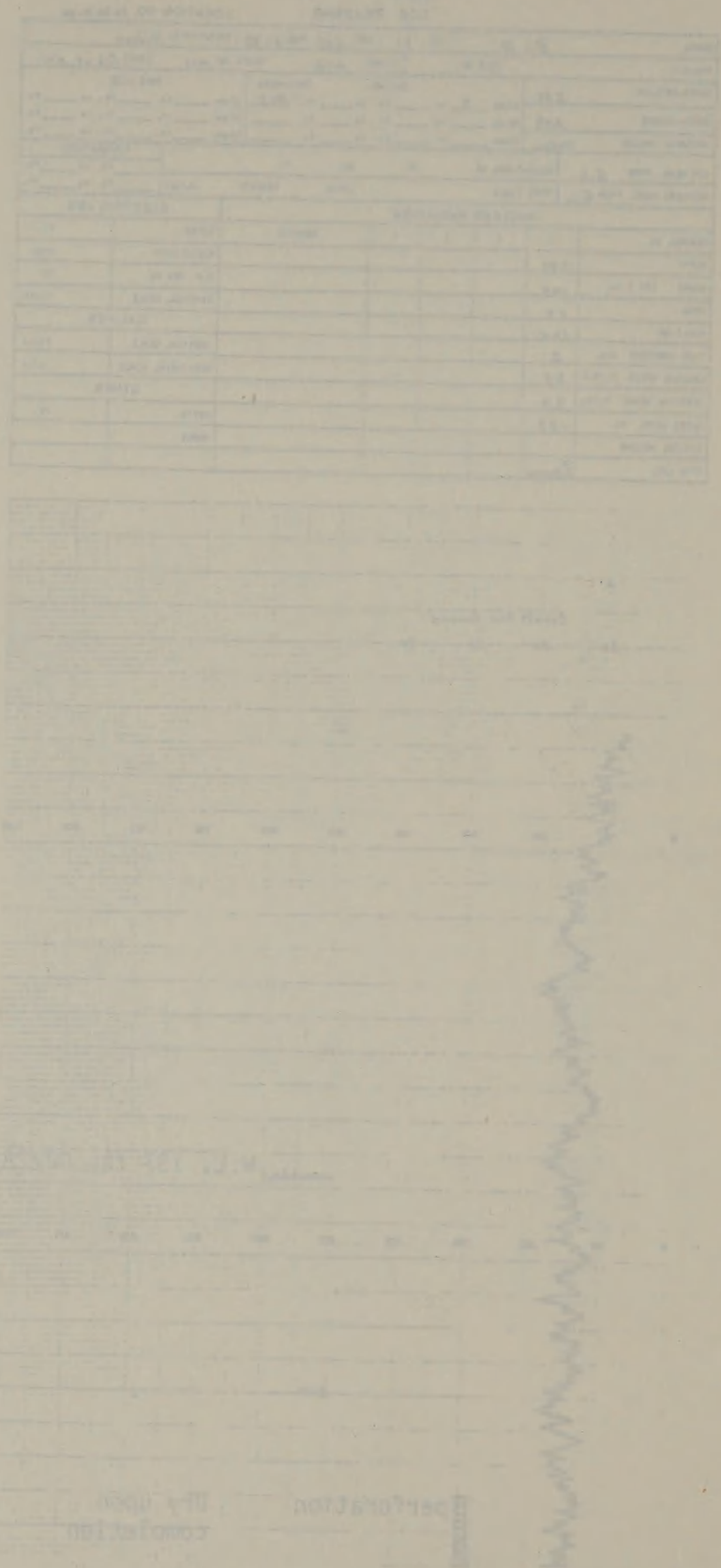
OWNER	B.L.M	SEC. 31	TWP. 20S	RNG. 32E	OPERATOR(S) Hudson
PROJECT		HOLE NO.	COUNTY Lea	STATE N. Mex.	DATE Feb 28, 1979
DEPTH-DRILLER	250	CASING Diam. 3 in. ____ Ft. to ____ Ft.	THICKNESS PVC	BORE SIZE Diam. ____ in. ____ Ft. to ____ Ft.	
DEPTH-LOGGER	249	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.	
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.		Diam. ____ in. ____ Ft. to ____ Ft.	
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.
DRILLERS MEAS. FROM	G.L.	TYPE FLUID	LEVEL	DENSITY	Lb/Gal

PERFORATIONS ____ Ft. to ____ Ft.; ____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	249					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	1					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	137					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

21.29.2.14

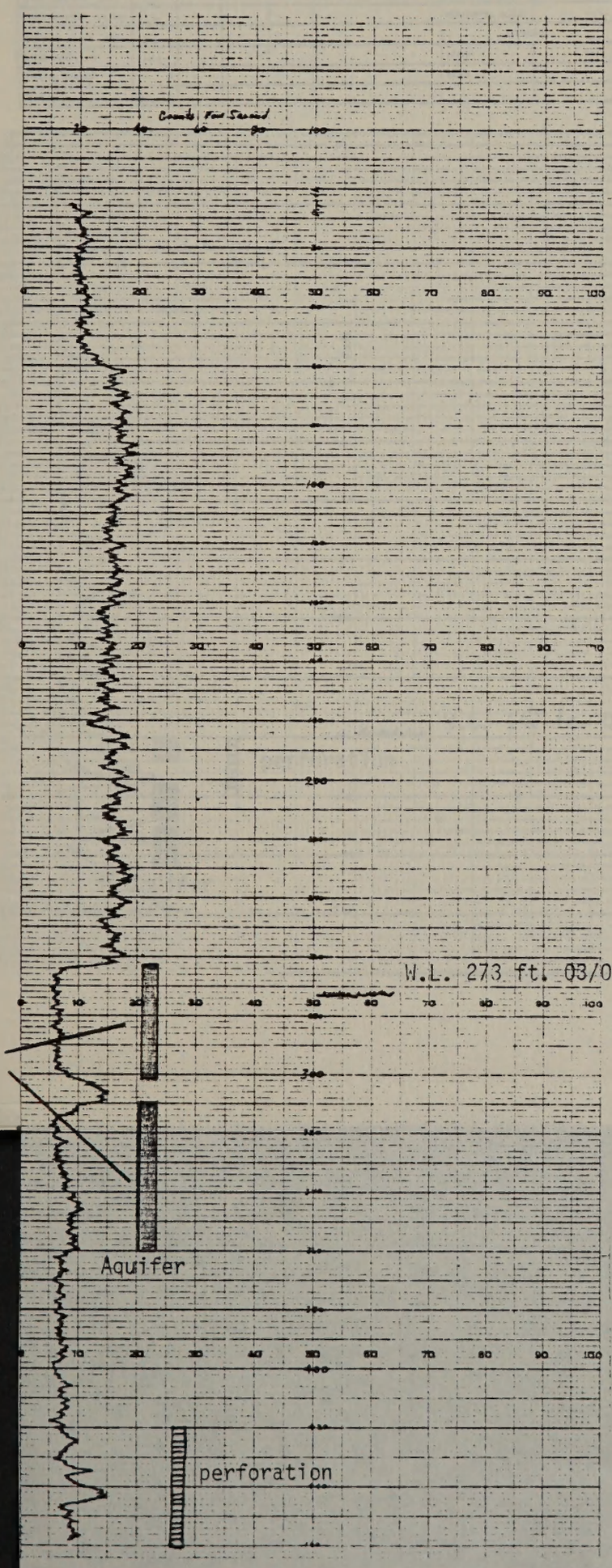
LOG HEADING

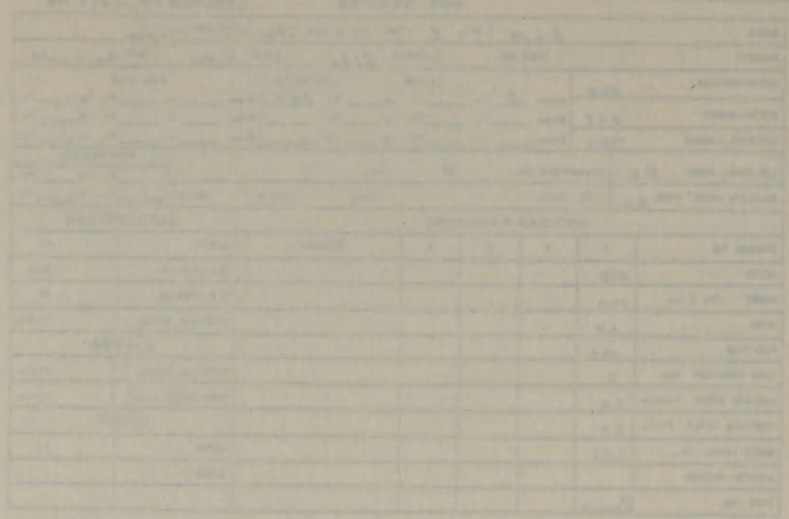
LOCATION NO. 21.29.2.Aa

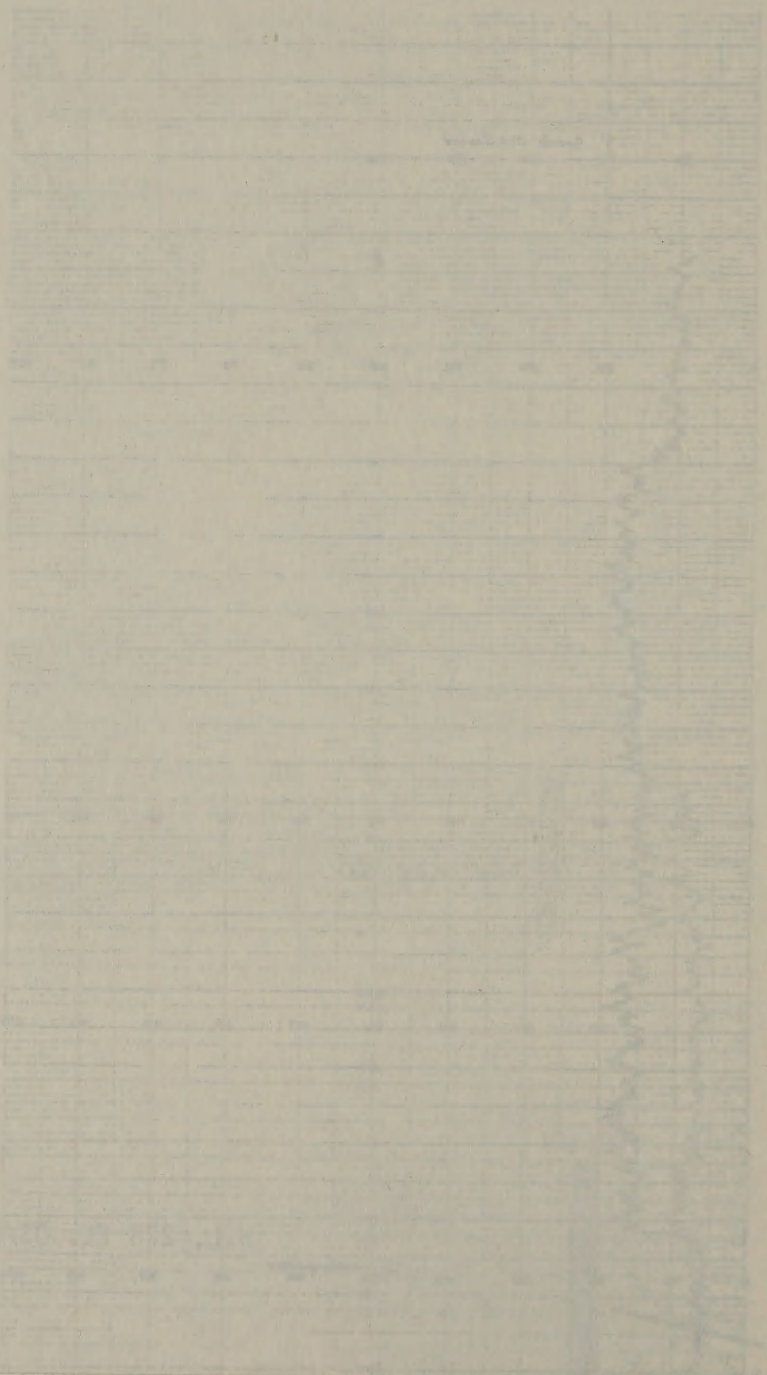
OWNER	B.L.M.	SEC. 2	TWP. 21 S	RNG. 29 E	OPERATOR(S) Hudson		
PROJECT	HOLE NO.	COUNTY Eddy	STATE N. Mex.	DATE Mar 1, 1979			
DEPTH-DRILLER 460	CASING	THICKNESS	BORE SIZE				
DEPTH-LOGGER 458	Diam. 3 in. ___ Ft. to ___ Ft.	P.V.C.	Diam. ___ in. ___ Ft. to ___ Ft.				
INTERVAL LOGGED Total	Diam. ___ in. ___ Ft. to ___ Ft.		Diam. ___ in. ___ Ft. to ___ Ft.				
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS		
DRILLERS MEAS. FROM G.L.	TYPE FLUID	LEVEL	DENSITY	Lb/Gal	___ Ft. to ___ Ft.		

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	458					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PER NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	1					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	273					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test







Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

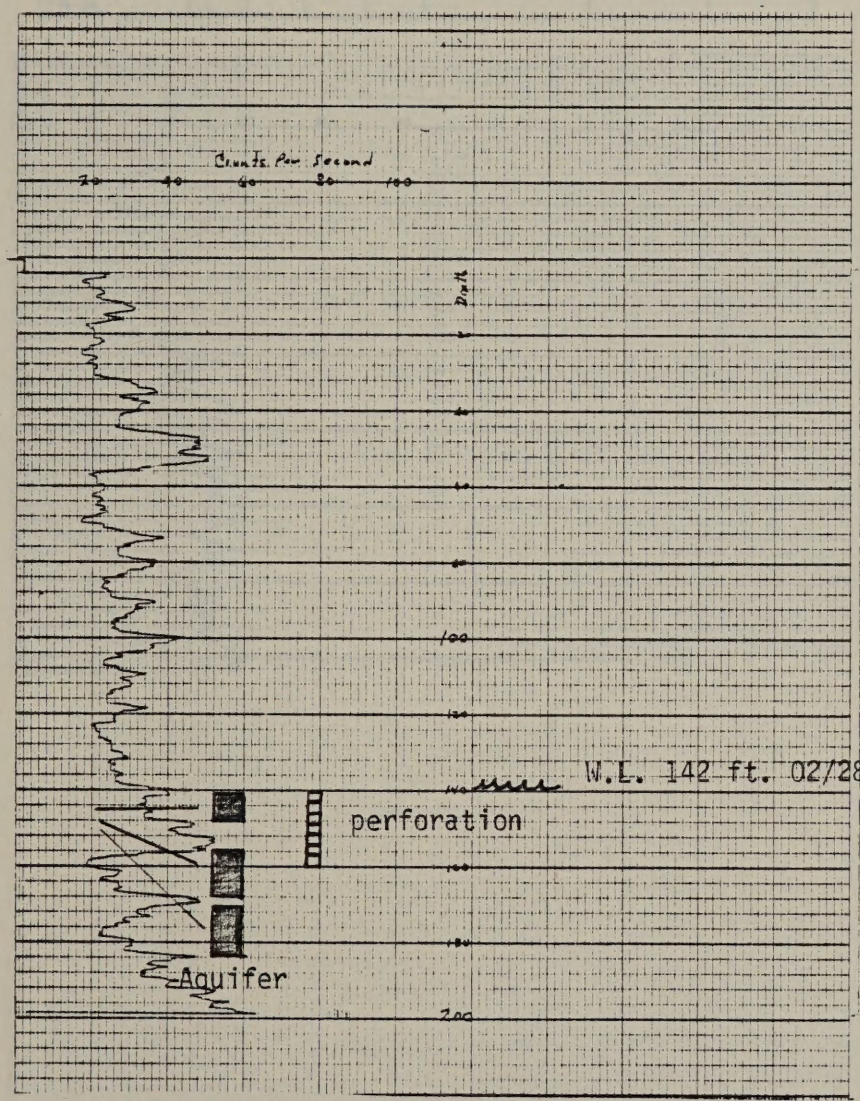
21.31.3.22

LOG HEADING

LOCATION NO. 21.32.3.444

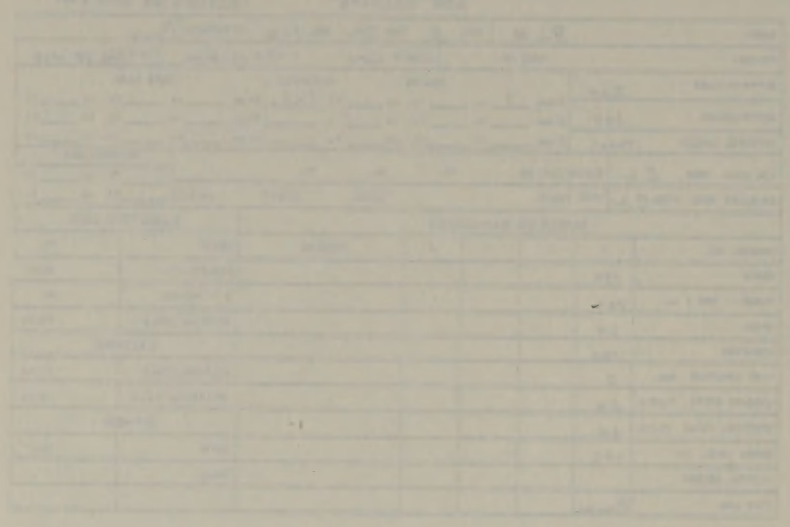
OWNER	B.L.M.	SEC. 3	TWP. 21s	RNG. 32E	OPERATOR(S) Cruz
PROJECT	HOLE NO.	COUNTY Lea	STATE N. Mex.	DATE Feb 28, 1979	
DEPTH-DRILLER	200	CASING Diam. 3 in. ____ Ft. to ____ Ft.	THICKNESS PVC.	BORE SIZE Diam. ____ in. ____ Ft. to ____ Ft.	
DEPTH-LOGGER	199	Diam. ____ in. ____ Ft. to ____ Ft.	____	Diam. ____ in. ____ Ft. to ____ Ft.	
INTERVAL LOGGED	Total	Diam. ____ in. ____ Ft. to ____ Ft.	____	Diam. ____ in. ____ Ft. to ____ Ft.	
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS ____ Ft. to ____ Ft.
DRILLERS MEAS. FROM G.L.	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.

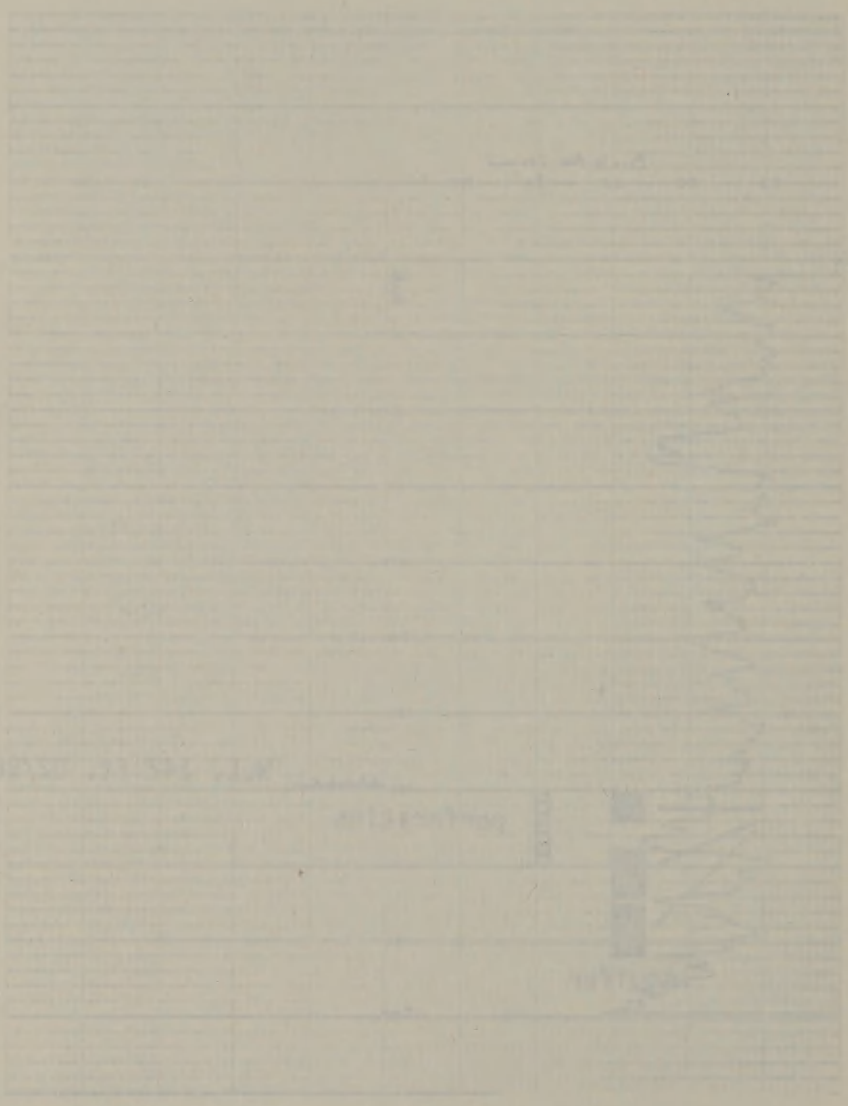
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	199					RESISTIVITY	Ohms
RANGE CPS 5 in.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	142					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



silty shale

Aquifer Test
Transmissivity
35 ft^2/day





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

21.31.15.33

LOG HEADING

LOCATION NO 21S 31E 15 33

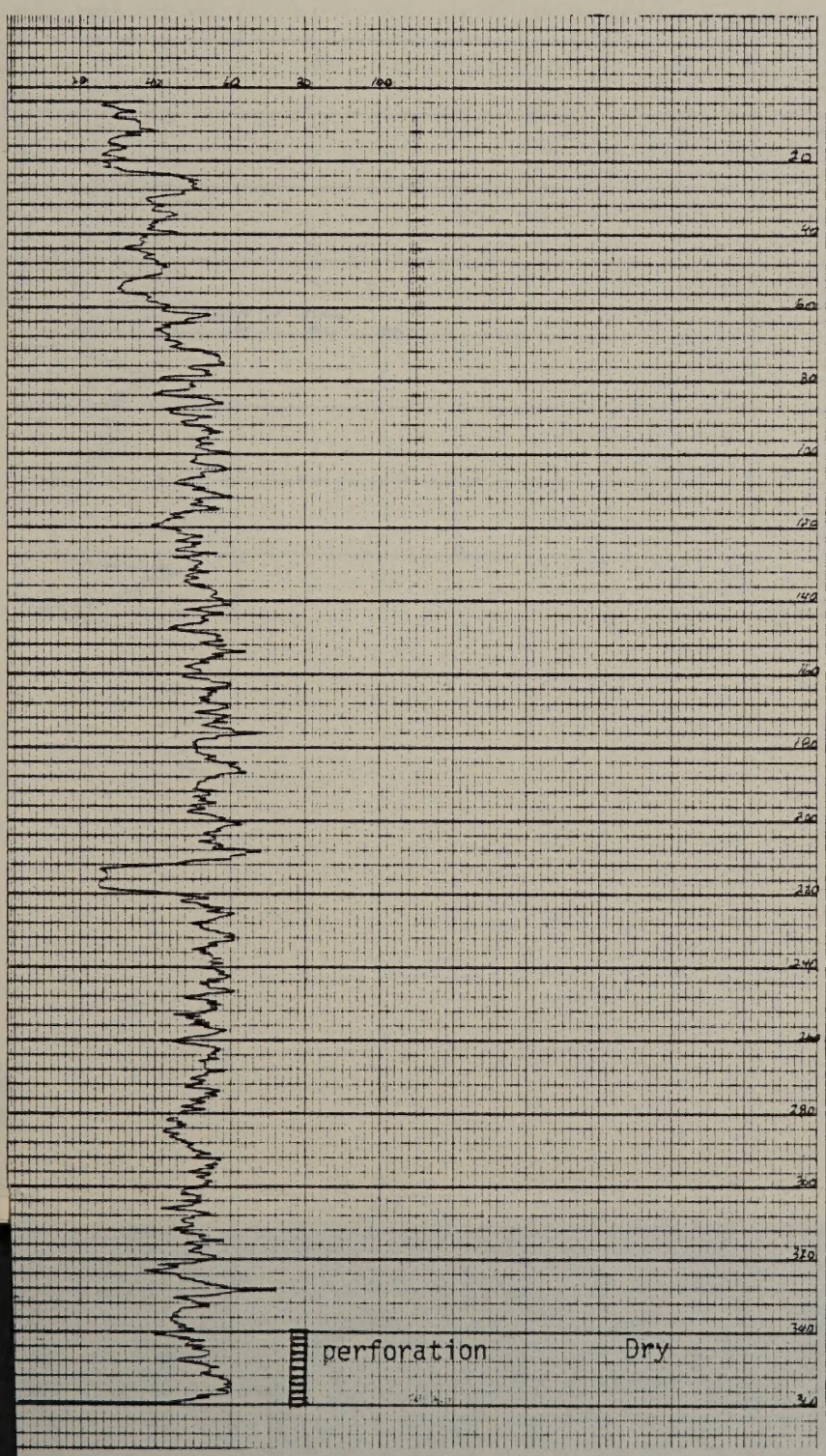
OWNER	BLM		SEC. 15	TWP. 21S	RNG. 31E	OPERATOR(S)	Cruz
PROJECT		HOLE NO.		COUNTY	Eddy	STATE N. Mex.	DATE 3/28/79

	CASING	THICKNESS	BORE SIZE
DEPTH-DRILLER	Diam. 3 In. 0 Ft. to 360 Ft.	PVC	Diam. ____ In. ____ Ft. to ____ Ft.
DEPTH-LOGGER 360	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.
INTERVAL LOGGED Top	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.

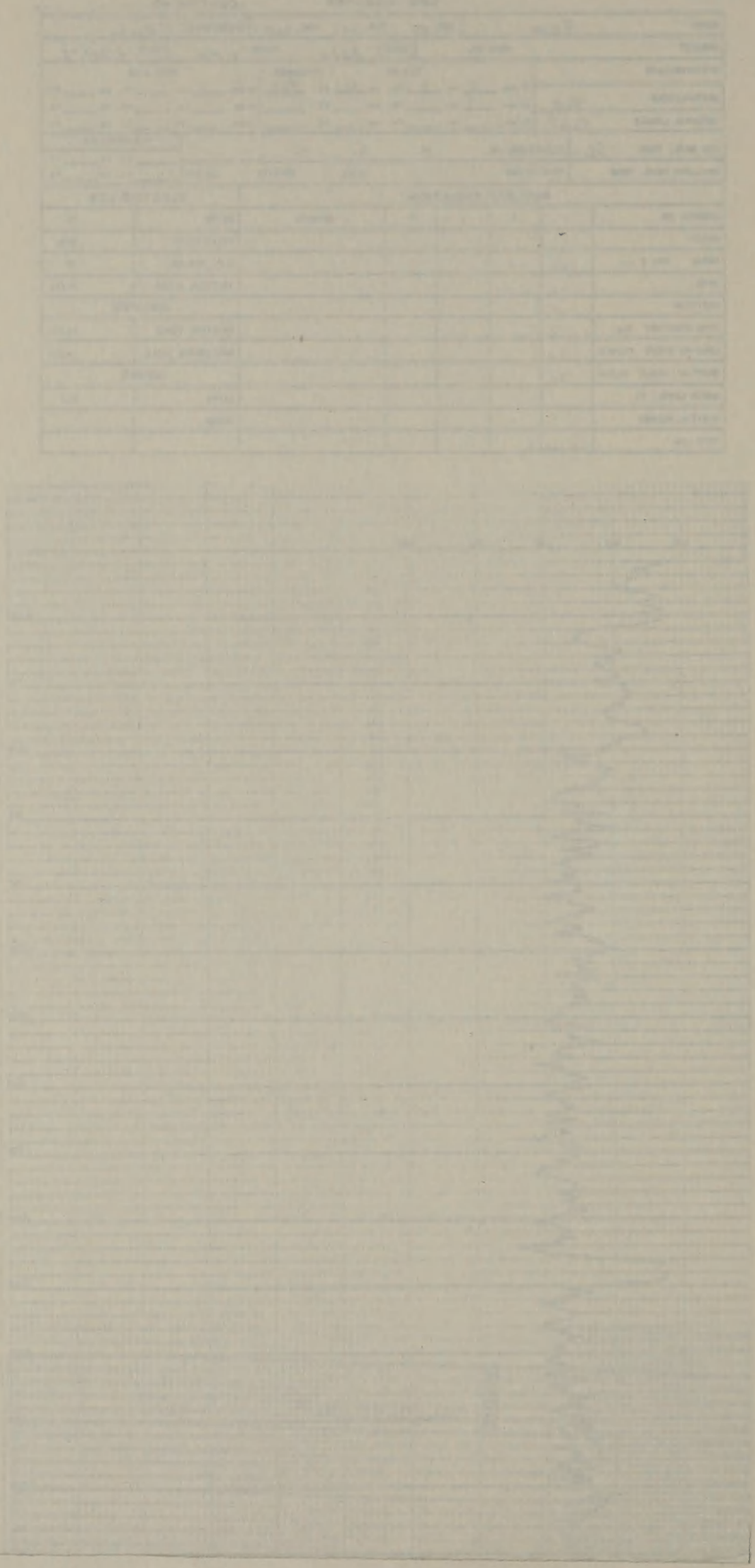
LOG MEAS. FROM GL	ELEVATIONS KB.	DF.	GL. TC.
DRILLERS MEAS. FROM	TYPE FLUID	LEVEL	DENSITY Lb/Gal

PERFORATIONS
____ Ft. to ____ Ft.
____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH						RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	10					VERTICAL SCALE	Ft/In
POSITION	10					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.						DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



No Test



Gamma logs, continued.

U.S. GEOLOGICAL SURVEY 23.28.1.110

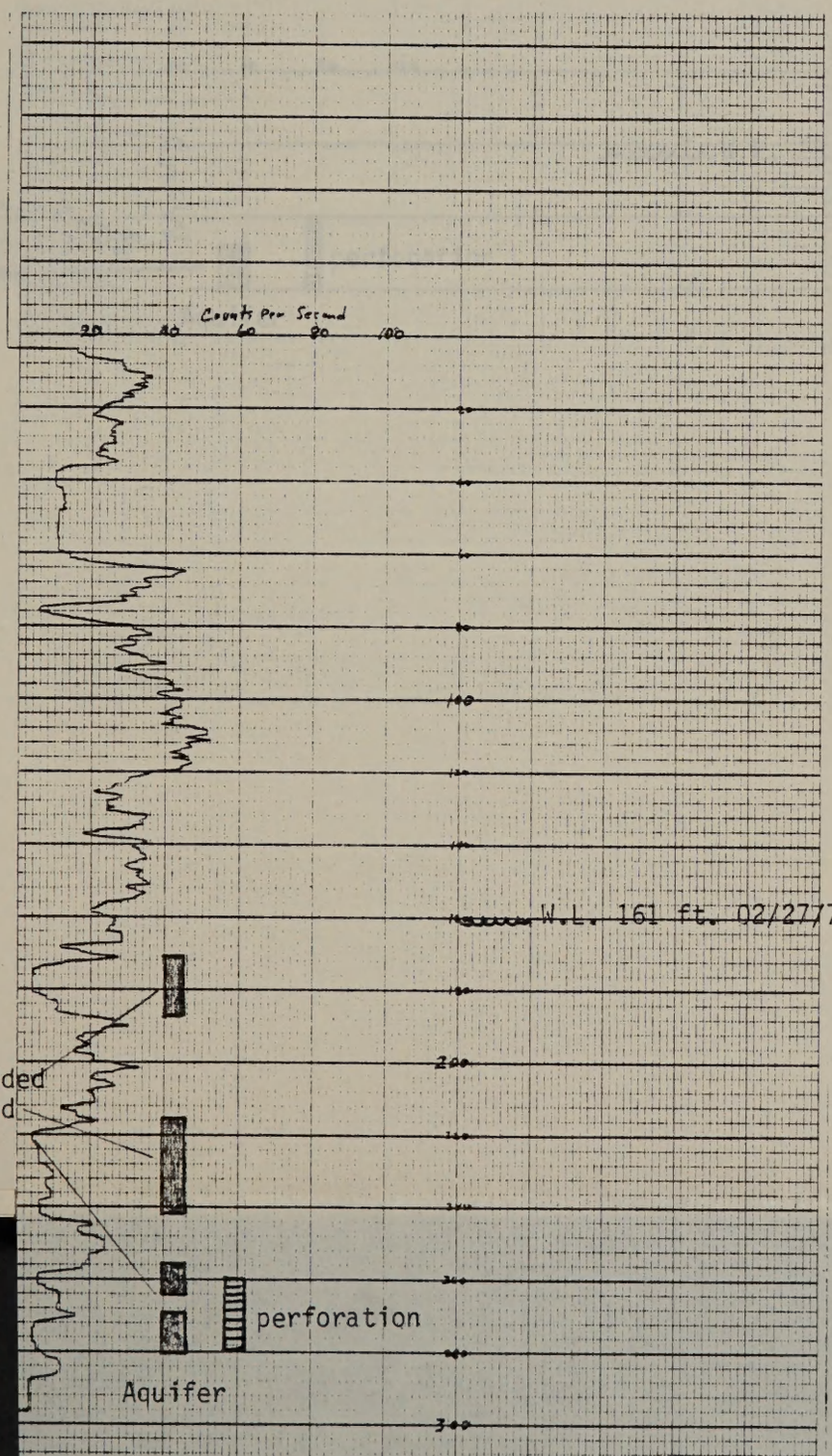
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

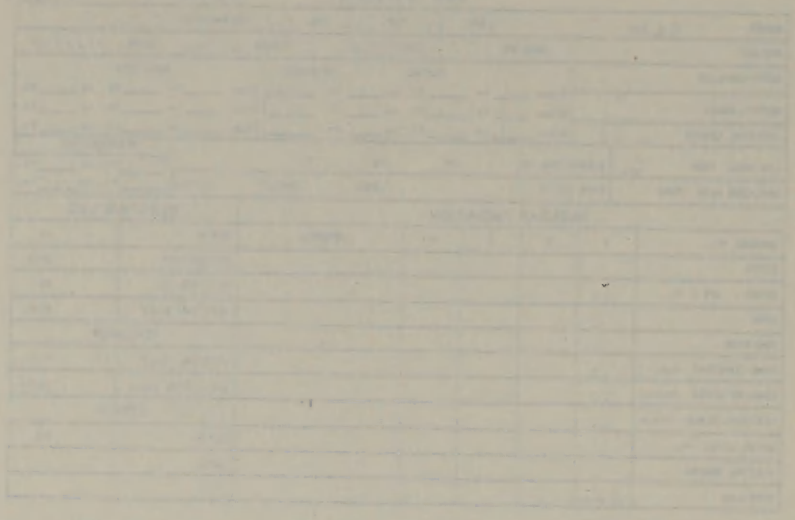
LOG HEADING LOCATION NO. 23.28.1.110

OWNER	B.L.M.	Sec. 1	TWP. 23 S	RNG. 28 E	OPERATOR(S) Cruz
PROJECT		HOLE NO. 1	COUNTY Eddy	STATE N. Mex	DATE Feb. 28, 1979
DEPTH-DRILLER	300	CASING	THICKNESS	BORE SIZE	
DEPTH-LOGGER	297	Diam. 3 In. ____ Ft. to ____ Ft.	P.V.C.	Diam. ____ In. ____ Ft. to ____ Ft.	
INTERVAL LOGGED	total	Diam. ____ In. ____ Ft. to ____ Ft.		Diam. ____ In. ____ Ft. to ____ Ft.	
LOG MEAS. FROM	G.L.	ELEVATIONS KB.	DF.	GL.	TC.
DRILLERS MEAS. FROM	G.L.	TYPE FLUID	LEVEL	DENSITY Lb/Gal	PERFORATIONS ____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	297					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	161					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

No Test





Gamma logs, continued.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

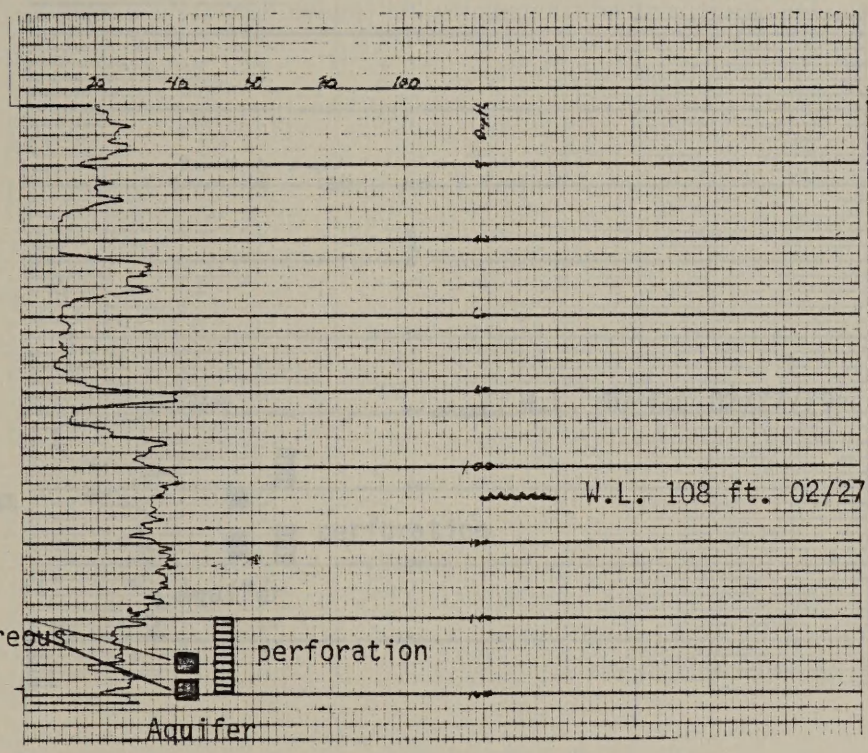
23.29.26.12

LOG HEADING

LOCATION NO. 23S.29E.26.12

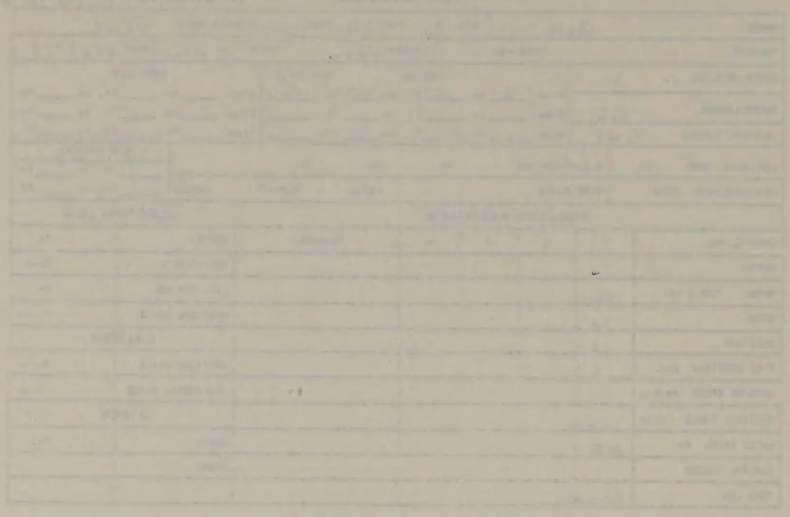
OWNER	BLM	SEC. 26	TWP. 23S	RNG. 29E	OPERATOR(S) Cruz
PROJECT	HOLE NO.	COUNTY Eddy	STATE N. Mex.		DATE 2/27/79
DEPTH-DRILLER	CASING THICKNESS			BORE SIZE	
	Diam. 3 in. 0 Ft. to 162 Ft. PVC			Diam. ____ in. ____ Ft. to ____ Ft.	
DEPTH-LOGGER 162	Diam. ____ in. ____ Ft. to ____ Ft. ____			Diam. ____ in. ____ Ft. to ____ Ft.	
INTERVAL LOGGED Total	Diam. ____ in. ____ Ft. to ____ Ft. ____			Diam. ____ in. ____ Ft. to ____ Ft.	
LOG MEAS. FROM GL	ELEVATIONS KB.	DF.	GL.	TC.	PERFORATIONS ____ Ft. to ____ Ft.
DRILLERS MEAS. FROM	TYPE FLUID		LEVEL	DENSITY Lb/Gal	____ Ft. to ____ Ft.

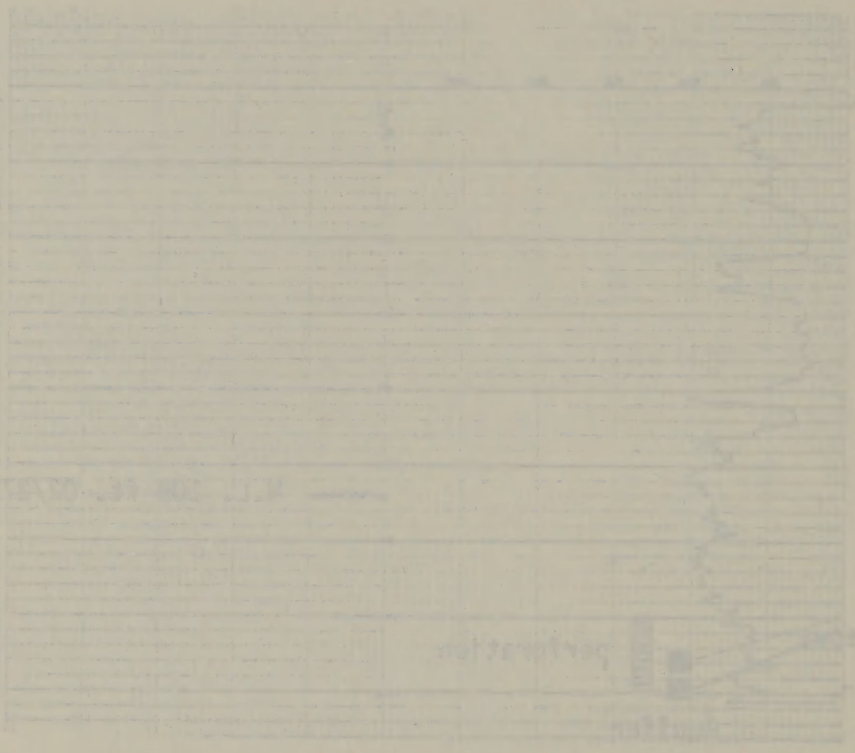
NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH						RESISTIVITY	Ohms
RANGE CPS 5 in.	150					S.P. PEN NO.	MV
SPAN	12					VERTICAL SCALE	Ft/In
POSITION	12					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	108					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						



hard calcareous shale

Slug Test
Transmissivity
0.13 ft^2/day





Gamma logs, concluded.

U.S. GEOLOGICAL SURVEY
WATER RESOURCES DIVISION
ALBUQUERQUE, NEW MEXICO

23.29.28.410

LOG HEADING

LOCATION NO. 23.29.28.410

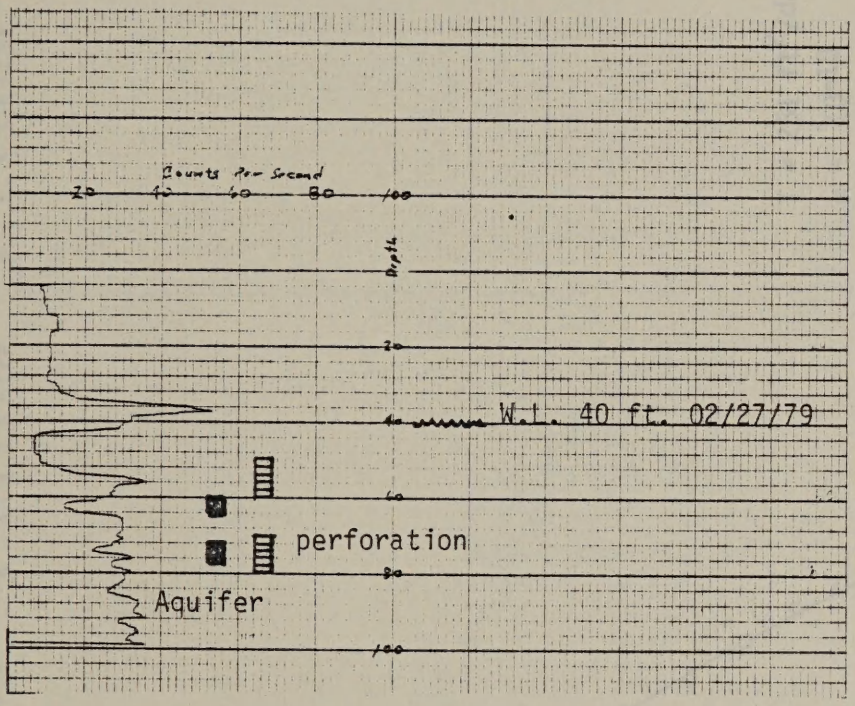
OWNER	BLM	SEC. 28	TWP. 23S	RNG. 29E	OPERATOR(S) Cruz
PROJECT	HOLE NO.	COUNTY Eddy	STATE N. Mex.		DATE Feb. 27, 1979

		CASING	THICKNESS	BORE SIZE
DEPTH-DRILLER	100	Diam. 3 In. ____ Ft. to ____ Ft.	P.V.C.	Diam. ____ In. ____ Ft. to ____ Ft.
DEPTH-LOGGER	99	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.
INTERVAL LOGGED	Total	Diam. ____ In. ____ Ft. to ____ Ft.	____	Diam. ____ In. ____ Ft. to ____ Ft.

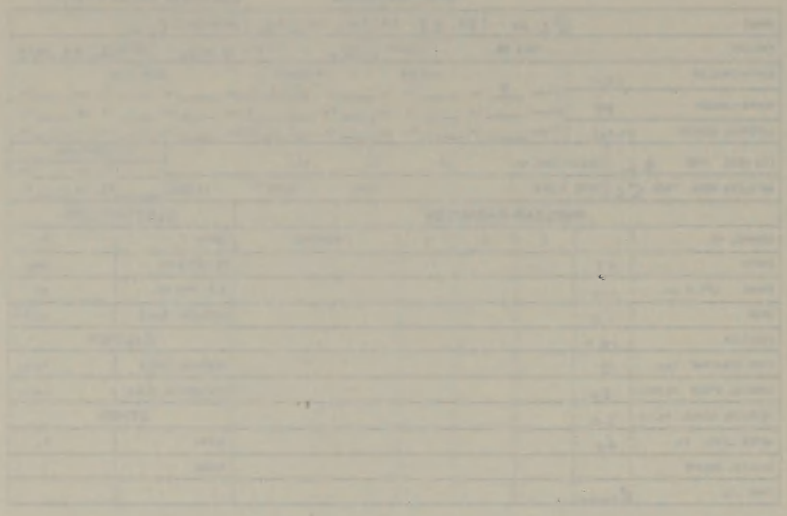
LOG MEAS. FROM G.L.	ELEVATIONS KB.	DF.	GL. TC.
DRILLERS MEAS. FROM G.L.	TYPE FLUID	LEVEL	DENSITY Lb/Gal

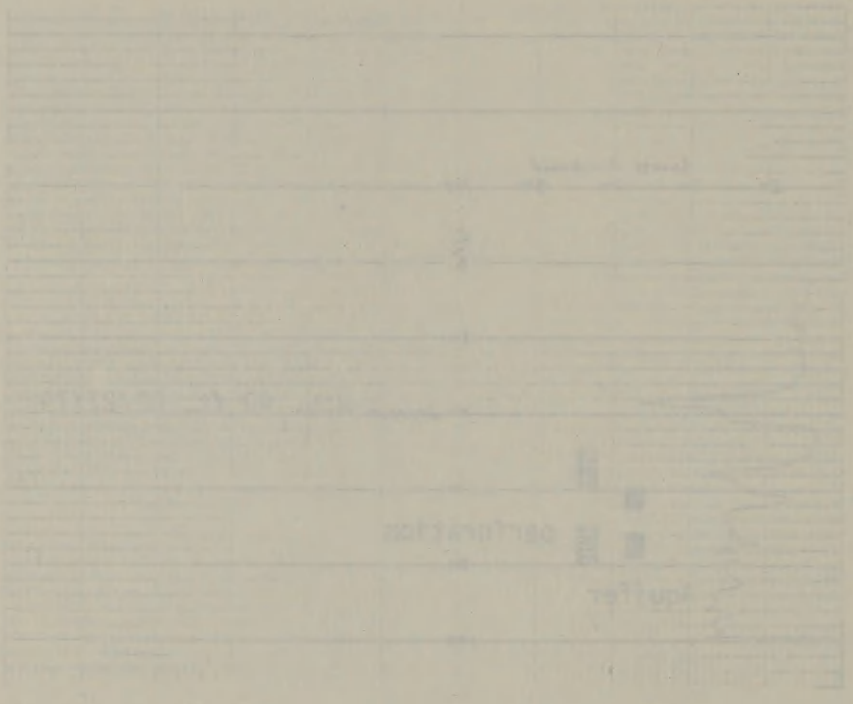
PERFORATIONS
____ Ft. to ____ Ft.
____ Ft. to ____ Ft.

NUCLEAR RADIATION						ELECTRIC LOG	
CHANNEL NO.	1	2	3	4	REMARKS	DEPTH	Ft.
DEPTH	99					RESISTIVITY	Ohms
RANGE CPS 5 In.	100					S.P. PEN NO.	MV
SPAN	1.0					VERTICAL SCALE	Ft/In
POSITION	10.0					CALIPER	
TIME CONSTANT Sec.	2					VERTICAL SCALE	Ft/In
LOGGING SPEED Ft/Min	20					HORIZONTAL SCALE	In/In
VERTICAL SCALE Ft/In	20					OTHER	
WATER LEVEL Ft.	40					DEPTH	Ft.
DIGITAL RECORD						RANGE	
TYPE LOG	Gamma						

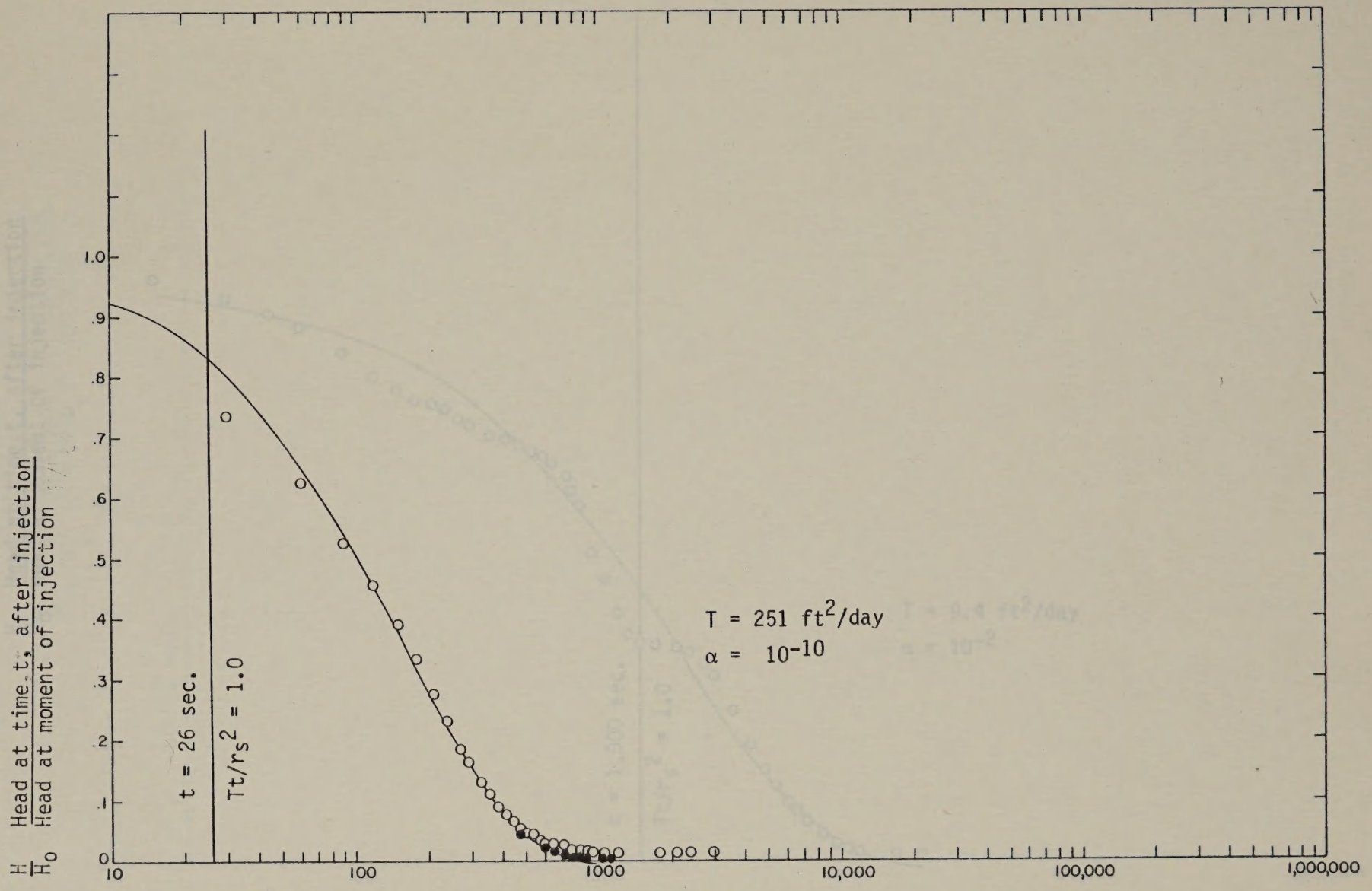


Aquifer Test
Transmissivity
40 ft^2/day



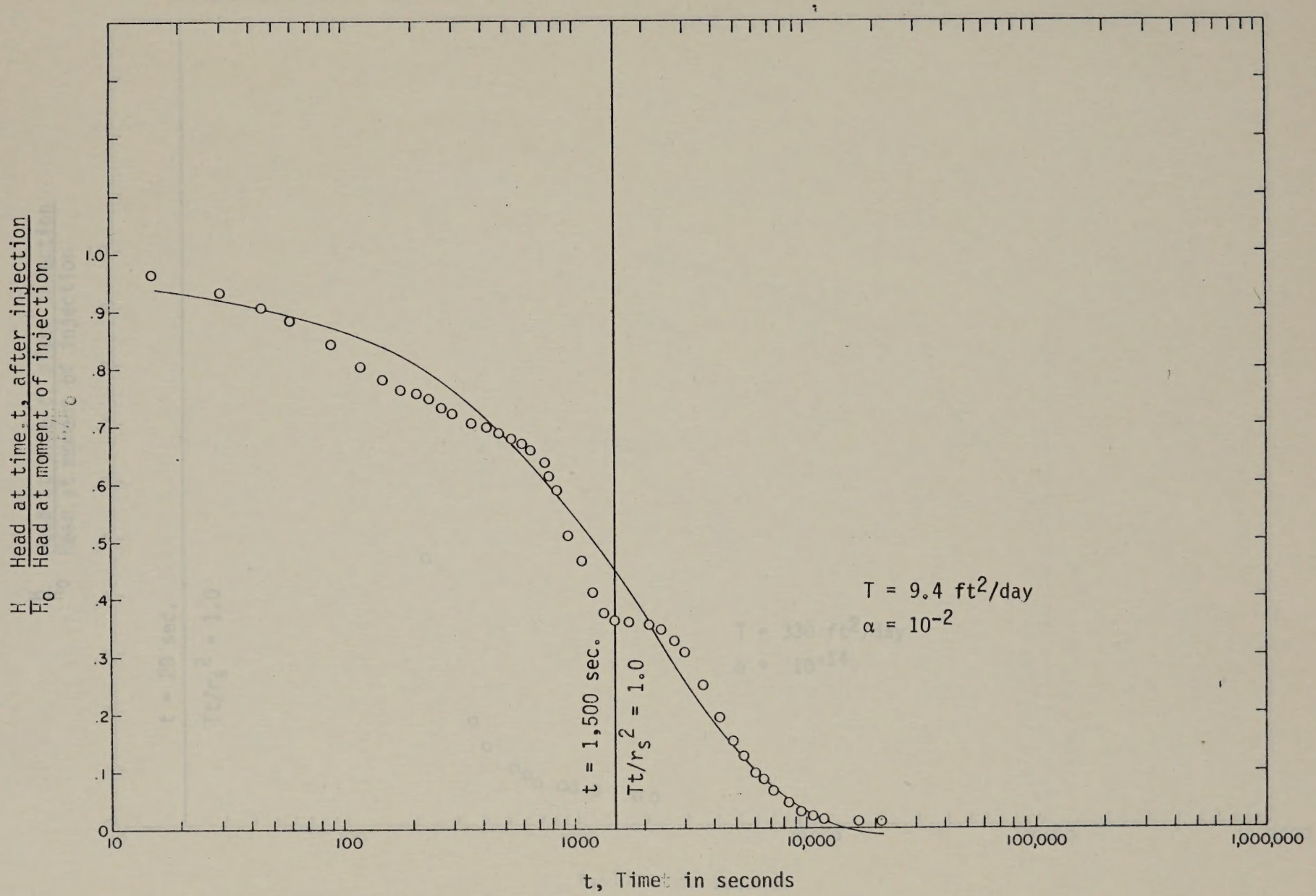


Slug-test data.

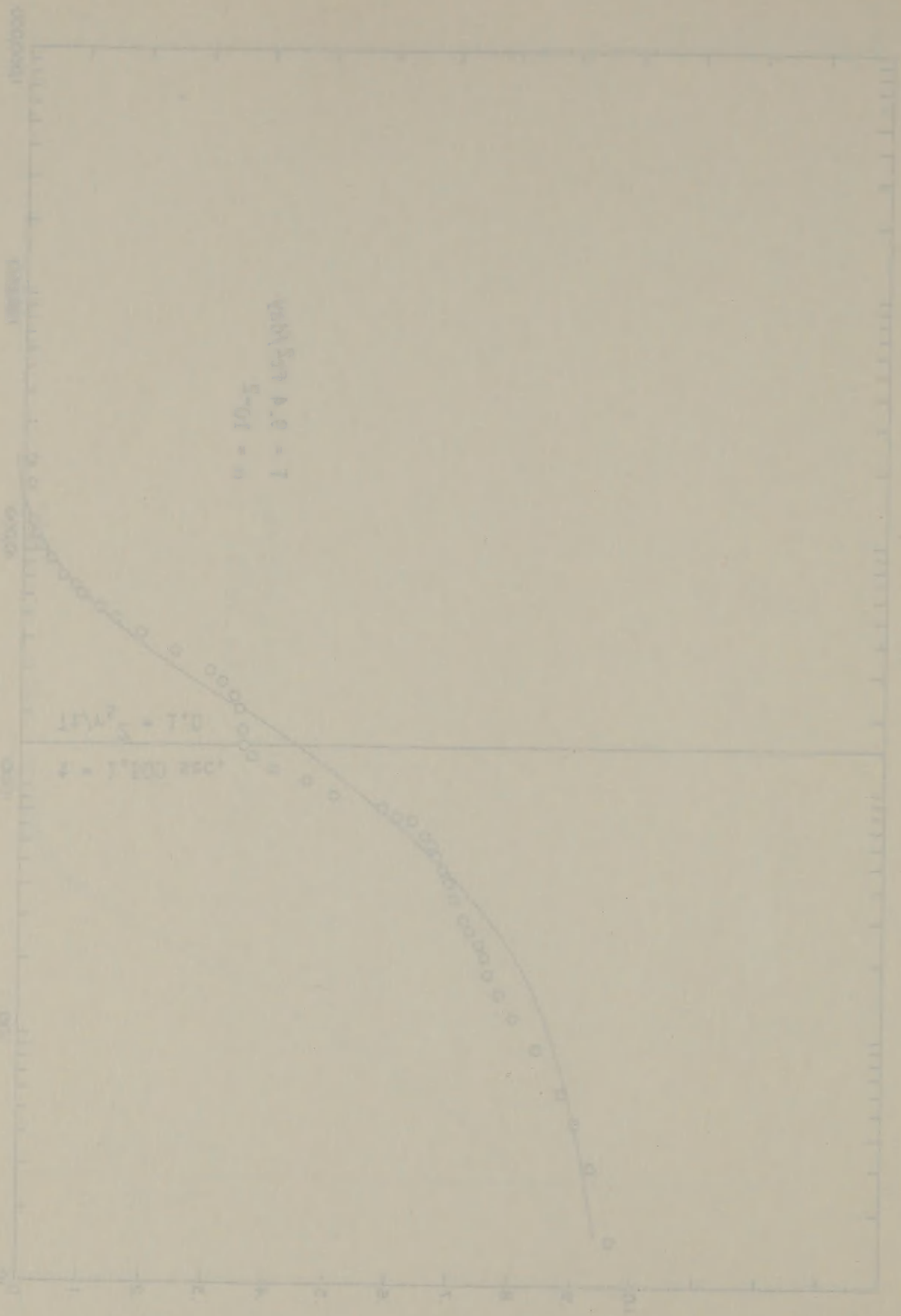


Plot of data from slug test on well at 19.30.24.133.

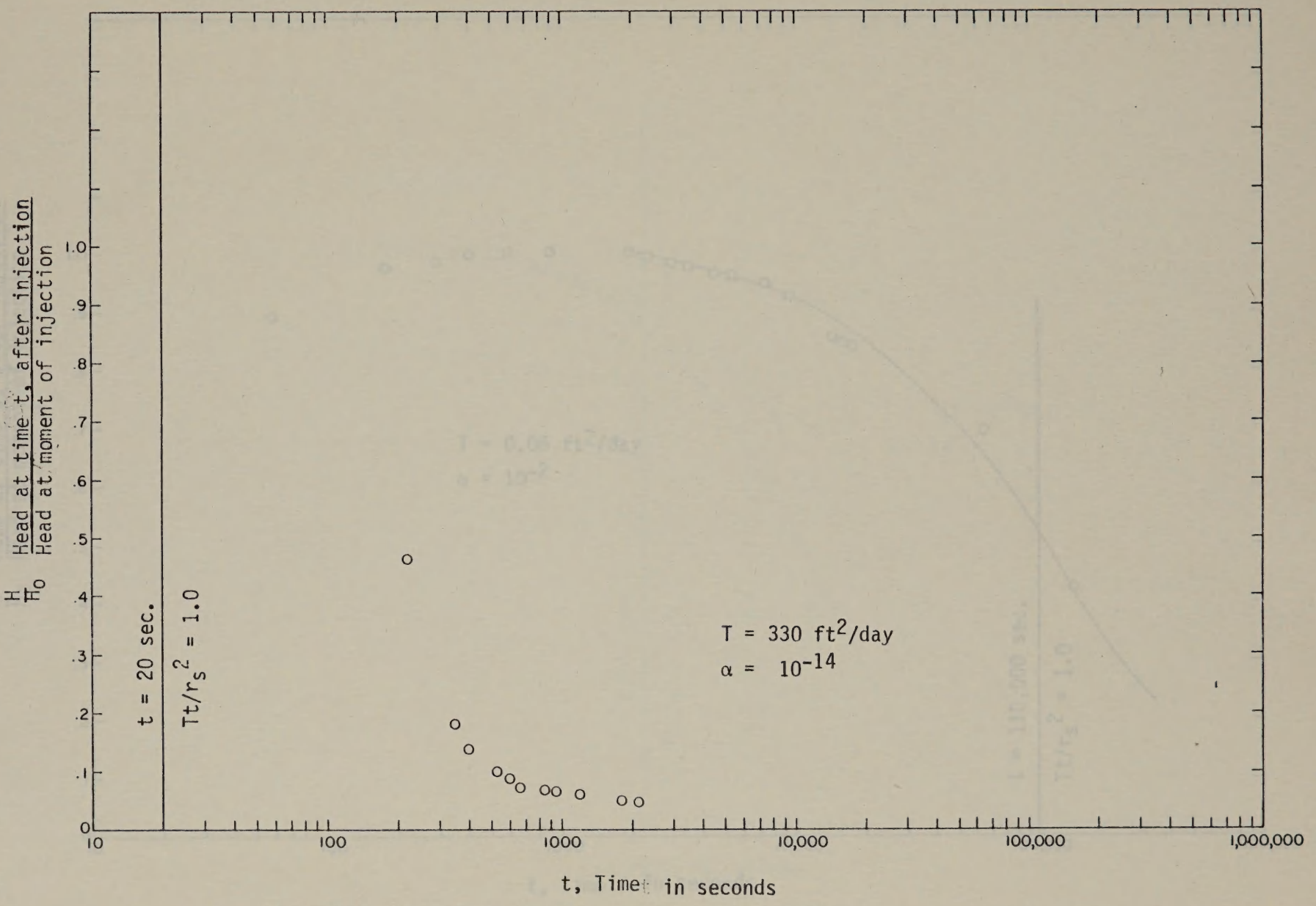
Slug-test data.



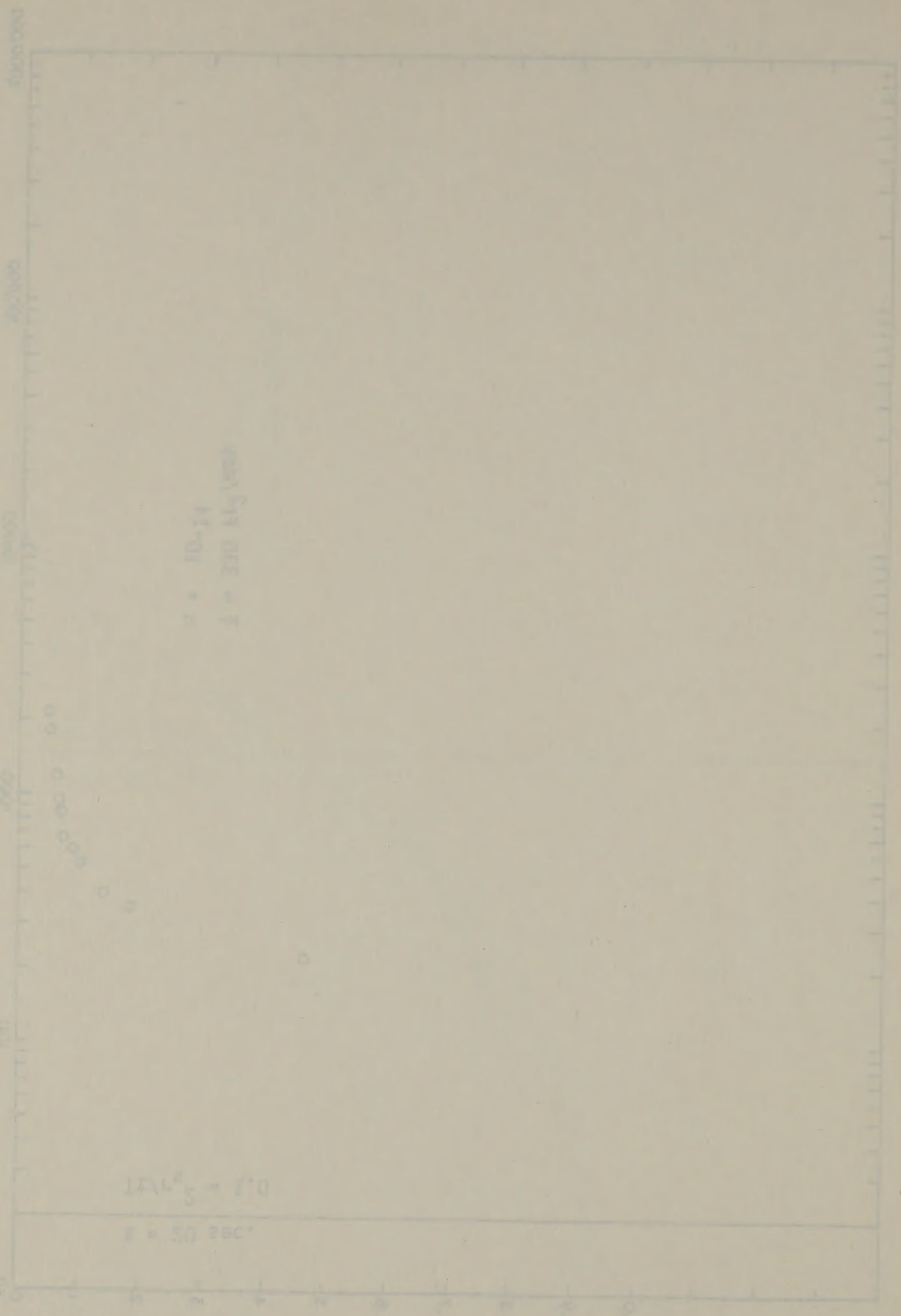
Plot of data from slug test on well at 19.30.35.23.



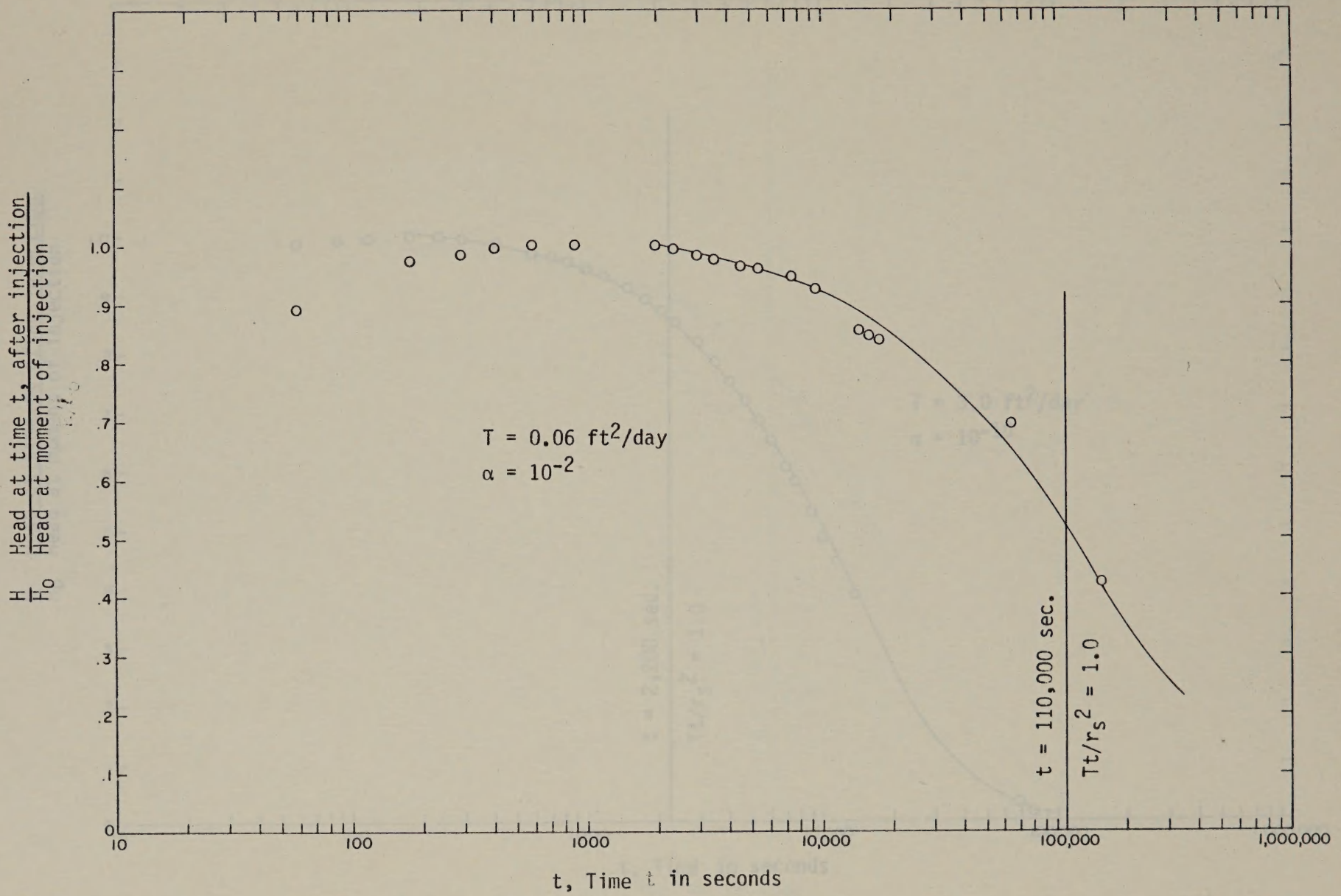
Slug-test data.



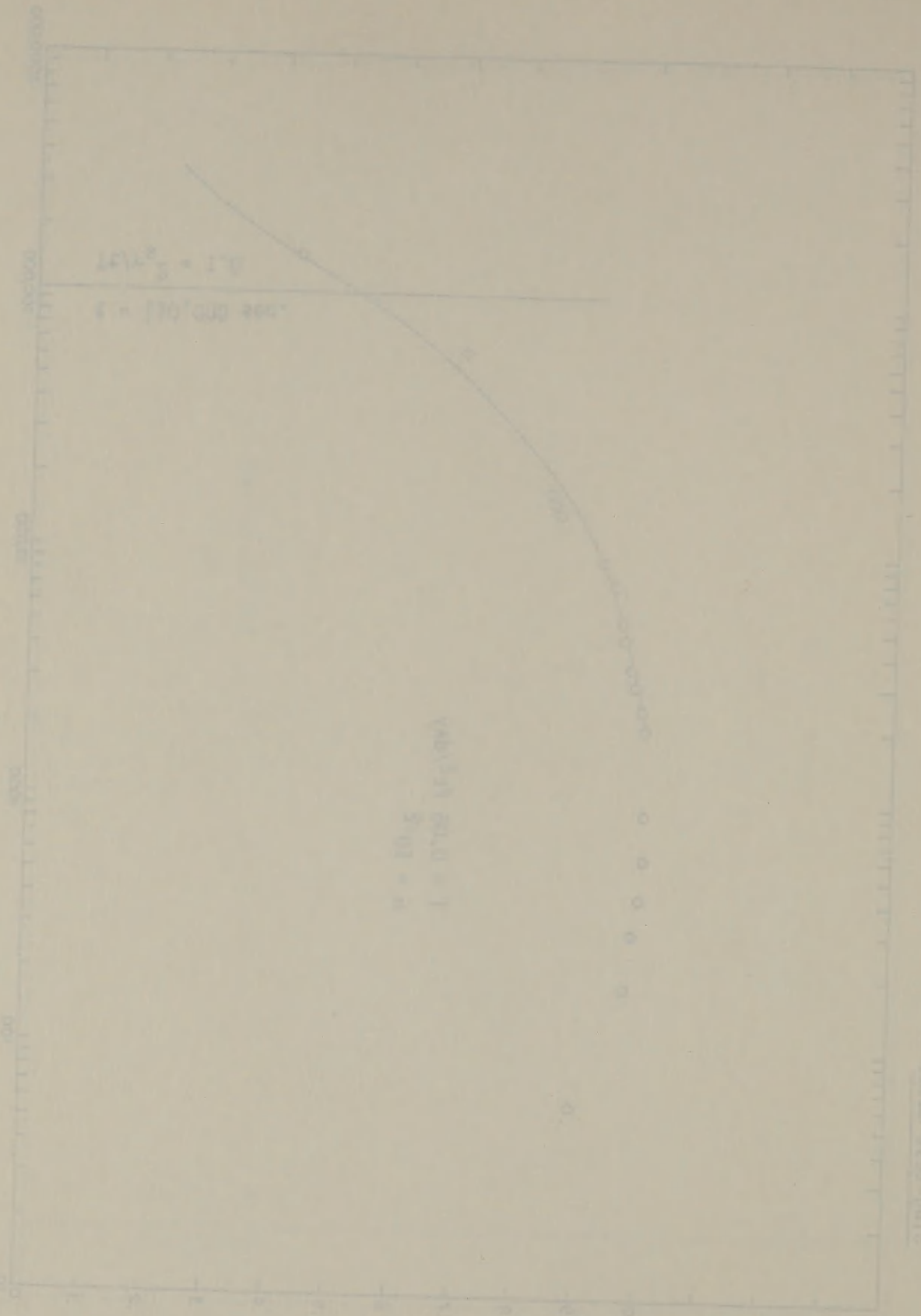
Plot of data from slug test on well at 20.29.25.33.



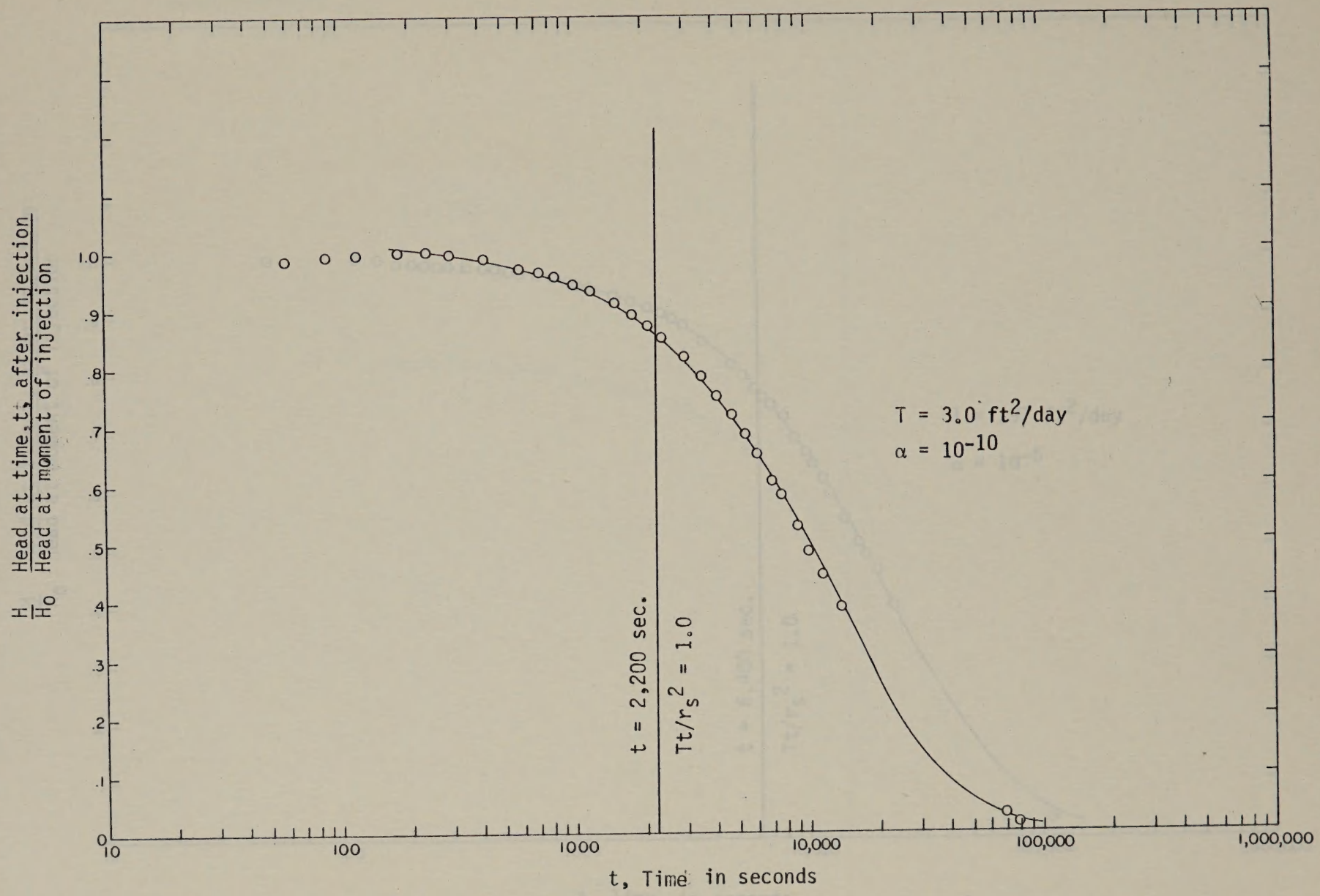
Slug-test data.



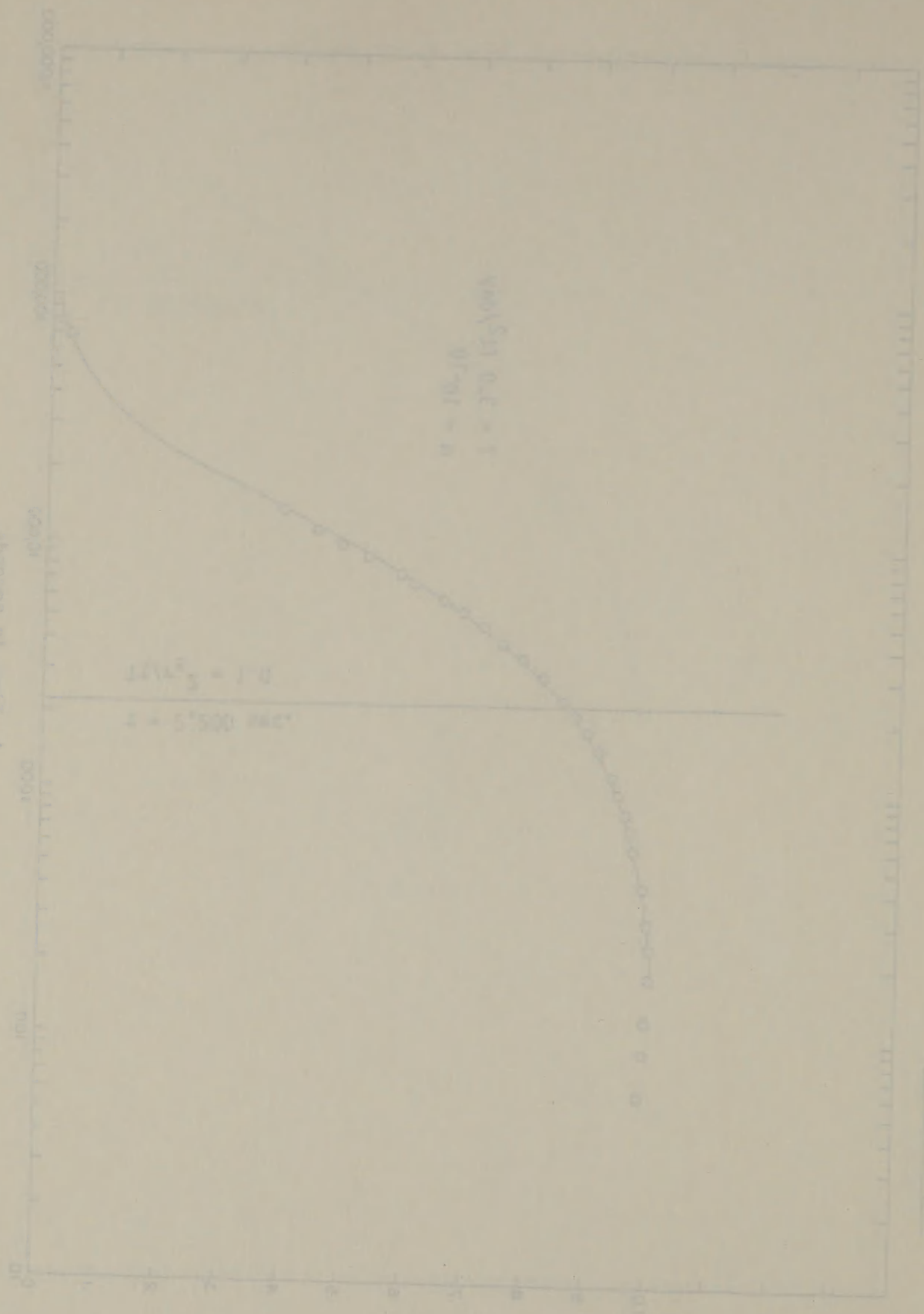
Plot of data from slug test on well at 20.30.28.44.



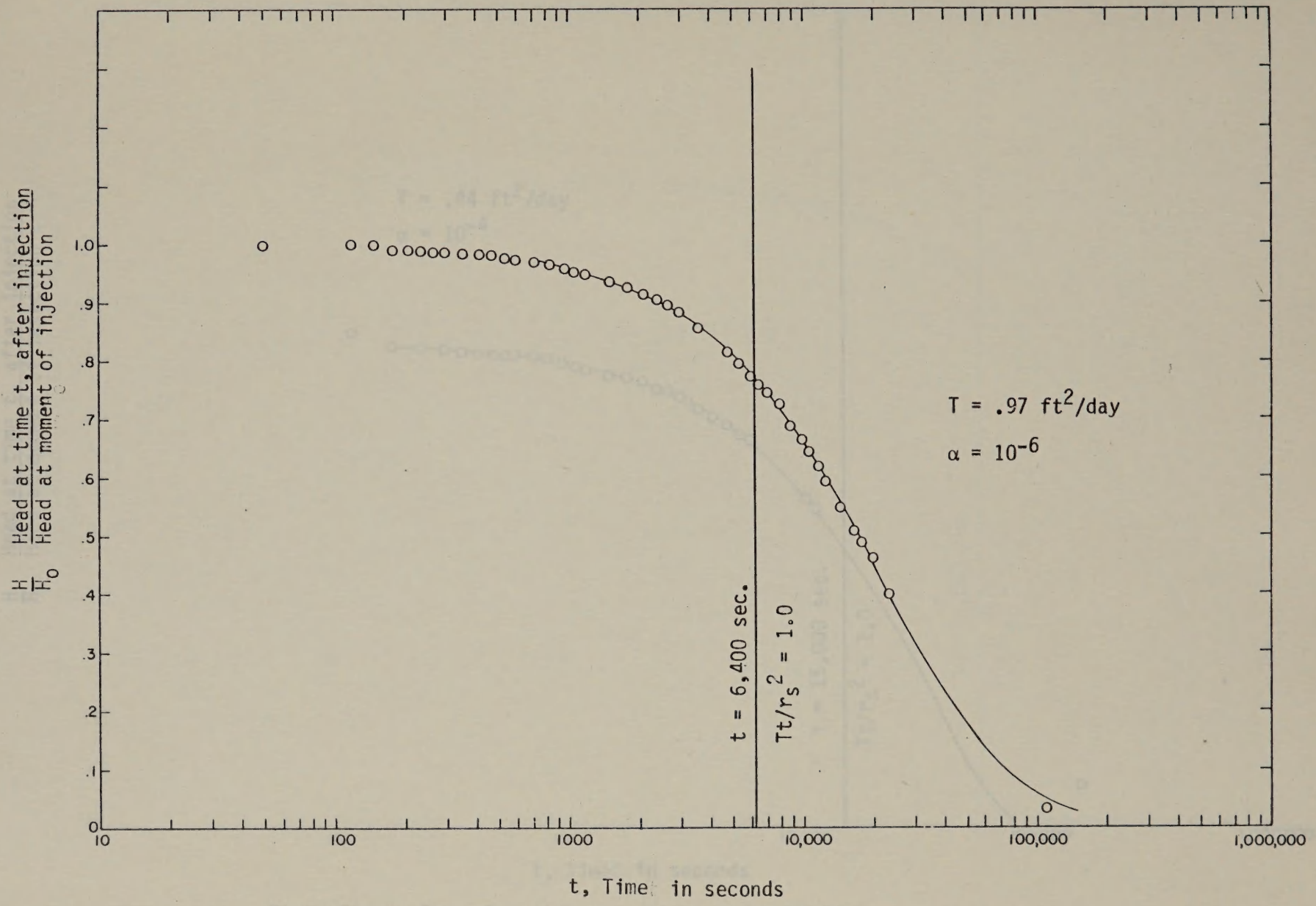
Slug-test data.



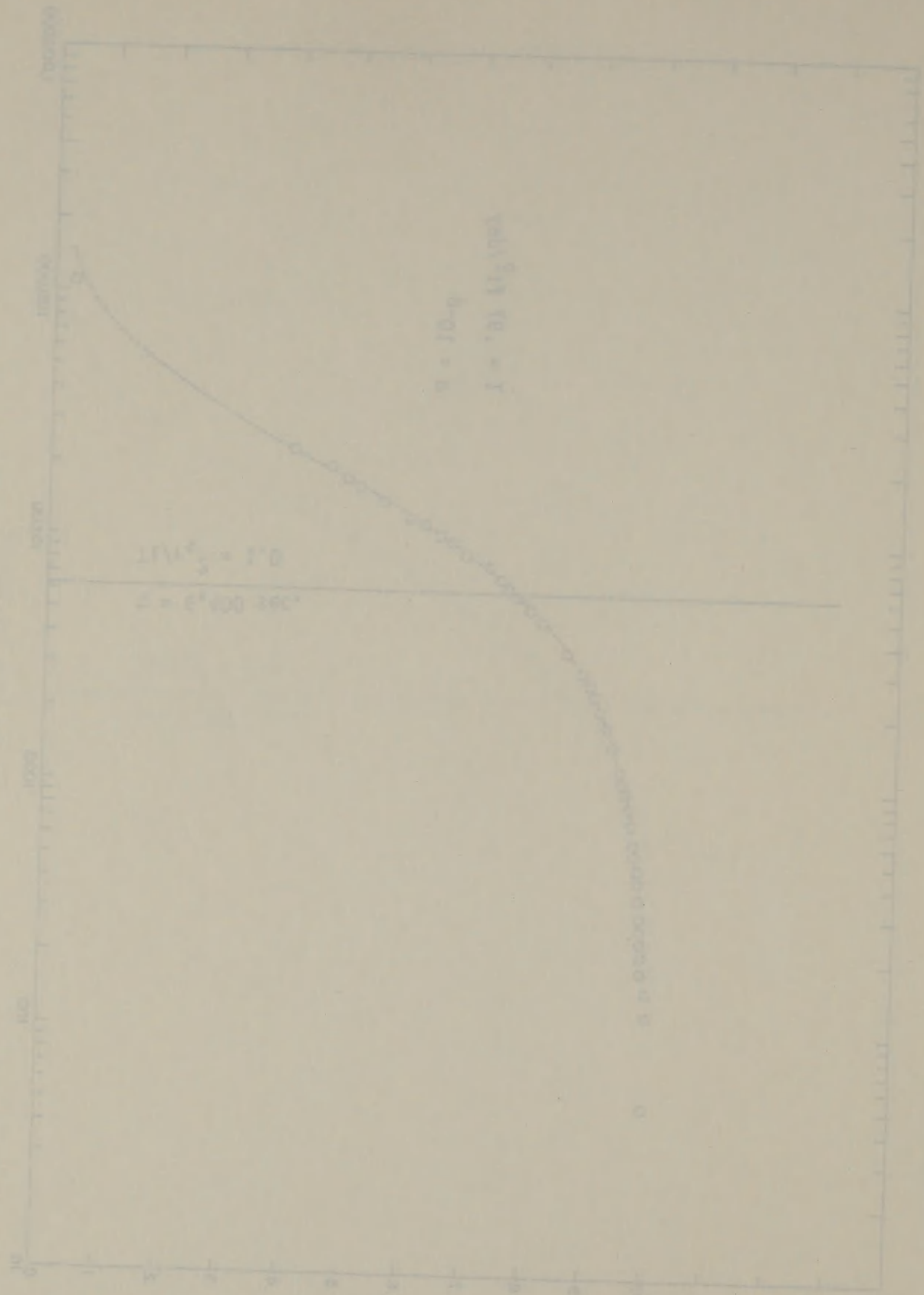
Plot of data from slug test on well at 20.30.29.33.



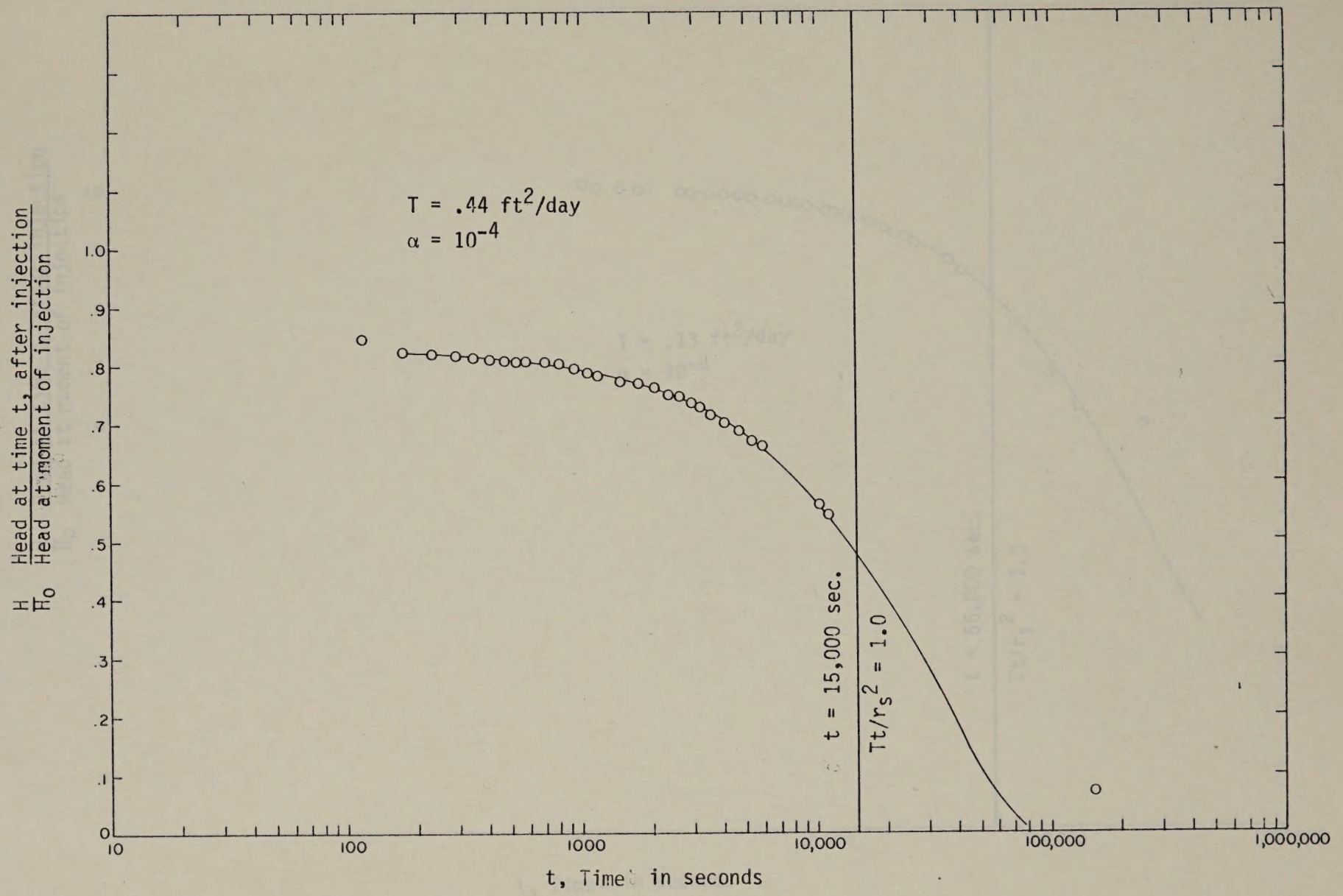
Slug-test data.



Plot of data from slug test on well at 20.31.2.34.

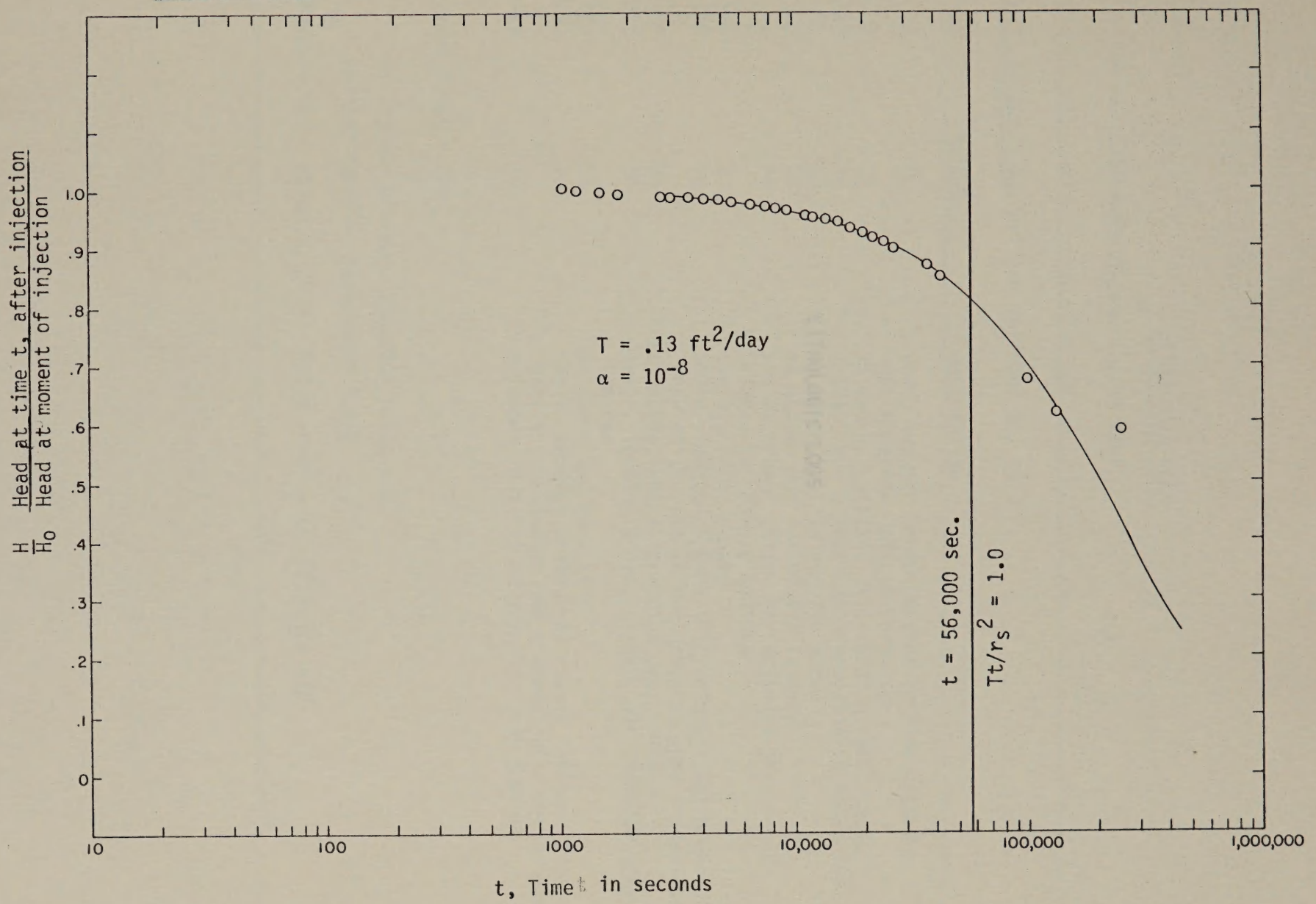


Slug-test data.



Plot of data from slug test on well at 20.31.27.24.

Slug-test data.



Plot of data from slug test on well at 23.29.26.12.

LITHOLOGIC LOGS

LITHOLOGIC LOGS

Top and Thickness figures are in feet.

Well 19.30. 3.44; drilled November 14, 1978

Top	Thickness	Description
0	20	sand, reddish brown, medium to fine texture, has moderate caliche formation
20	12	as above, but less calcareous mineralization
32	20	shale, red, silty, has greenish gray inclusions
52	10	as above, but is reddish brown
62	20	as above, but has clayey laminae
82	48	shale, brown, silty, has greenish gray inclusions, has clayey laminae
130	10	shale, brown, clayey
140	10	shale, reddish brown, silty-clayey, has greenish-gray silty laminae and greenish gray inclusions
150	20	as above, but no greenish gray laminae
170	10	shale, reddish brown, clayey, has greenish gray laminae
180	10	as above but more silt
190	20	shale, reddish brown, has clayey laminae, greenish gray silty laminae and greenish gray inclusions
210	10	as above, but has no greenish gray laminae

Total Depth - 220

Casing perforated - 200-220' below LSD

Bailing results - estimates ½ gpm

Measurement: March 1, 1979: Water level - 143.0' below LSD

Lithologic logs, continued.

Well 19.30. 5.32; drilled November 7, 1978

Top	Thickness	Description
0	6	sand, brown buff, medium to fine texture (aeolian) 4" organic profile
6	8	caliche, buff, mild to moderate formation
14	16	sand, quartz, pinkish brown, medium to fine texture, calcareous, slightly cohesive
30	9	as above, but more lithified and less calcareous
39	20	sand, quartz, brown-buff, medium to fine texture, calcareous, unconsolidated
59	11	sand, brown, medium texture, unconsolidated, slightly calcareous, predominantly quartz (subangular)
70	10	as above, but non-calcareous, medium-fine texture
80	10	as above, but slightly calcareous
90	10	as above, but non-calcareous, reddish brown
100	10	sand, brownish red, medium to fine texture, non-calcareous, has some clayey laminae
110	20	sand, brown-buff, medium texture, calcareous, quartz, subangular
130	10	sand, brown, medium to coarse texture, calcareous quartz, subangular, has some silt, caliche (small)
140	10	as above, but coarser quartz fragments and more silt, clay, small caliche fragments
150	20	sand, brown, medium texture slightly calcareous has silt, clay and small caliche fragments

Total Depth - 170'

Casing perforated - 130-150' below LSD
Bailing test - estimates 1 gpm
Water slightly salty

Drilled with mud from 90' to TD, silt and clay winnowed out in wash, probably more silt and clay than sand from 140' to TD
Measurement: March 1, 1979: Water level - 140' below LSD

Well 19.30.24.133; drilled November 7, 1978

Top	Thickness	Description
0	2	sand, brown buff, medium to fine texture, 4" of organics
2	6	caliche, brownish white medium formation
8	12	shale brownish red, silty with greenish gray inclusions
20	16	shale, brown, varigated silty to clayey with greenish gray inclusions

Lithologic logs, continued.

Well 19.30.24.133 continued

Top	Thickness	Description
36	4	shale, lavender-red, silty
40	10	shale, yellowish-red, silty to slightly clayey with greenish gray inclusions, slightly moist
50	10	as above, but browner in color
60		shale, brown silty, with some clayey laminae

Total Depth - 70'

Casing perforated - 50-70' below LSD
Bailing test - estimates 2 gpm
Taste very salty
Water level about 50' below LSD
Driller encountered reasonably moist sediments at 59' below LSD
Measurement: March 7, 1979: Water level - 52.13' below LSD

Well 19.30.33.31; drilled November 4, 1978

Top	Thickness	Description
0	18	clay, grayish-buff, calcareous (lacustrine deposit)
18	12	shale, red, clayey, has coarse crystalline amber selenite gypsum. calcareous
30	10	shale, brownish red, silty, has greenish gray inclusions and is calcareous
40	10	shale, brownish red, silty, has greenish gray inclusions, coarse crystalline selenite gypsum, calcareous

Total Depth - 50'

Driller encountered water at 39' below LSD
Casing penetrated - 30-50' below LSD
Bailing results - estimates 10 gpm
Water level 28' below LSD

Well 19.30.35.23; drilled November 7, 1978

Top	Thickness	Description
0	3	sand brown-buff, 6" organic profile, fine to medium texture, aeolian
3	11	caliche, pinkish white, moderate to strong formation
14	17	shale, sandy, reddish brown, calcareous, leached
31	9	as above, but with silty layers, generally finer texture
40	10	sand and gravel; sand-brownish buff, gravel-mixed lithologies, mostly chert, about 6mm in diameter

Lithologic logs, continued.

Well 19.30.35.23 continued

Top	Thickness	Description
50	10	as above, but with limestone of mixed origin (texture and color), fluvial gravel
60	24	shale, reddish brown, very clayey
84	16	shale, brownish red, clayey with some silt

Total Depth - 100'

Bailing test - estimates 1 gpm
Water level approximately 80' below LSD
Casing penetrated - 60-80' below LSD
Measurement: March 1, 1979: Water level - 81' below LSD

Well 19.32.29.32; drilled November 8, 1978

Top	Thickness	Description
0	11	caliche, white, moderate to strong formation
11	19	sand, brown-buff, unconsolidated aeolian, medium to fine texture
30	10	sand, buff, fine texture, weakly consolidated
40	10	as above, but lighter in color and has some silty laminae, small caliche nodules
50	10	shale, maroon, clayey, has greenish gray inclusions (elongated), concentrated along bedding, slightly moist
60	10	as above, but fewer greenish inclusions and contains rounded limestone fragments (aphanitic, red)
70	10	shale, variated red-buff, very clayey, also has limestone fragments mentioned above
80	10	limestone, crystalline (fine), mottled maroon to gray, has a few laminae of grayish-green, silty shale
90	10	limestone, fine crystalline, silty, maroon, has some greenish gray silty shale laminae and some minor clayey shale (red) laminae

Total Depth - 100'

Wet sediments encountered at 50'
Bailing test - dry ?
Casing perforated - 80-100' below LSD
Footage subtotal - 2,610'
Footage subtotal - 2,610'
Dry, March 15, 1979

Lithologic logs, continued.

Well 20.29.25.33; drilled November 7, 1978

Top	Thickness	Description
0	4	sand, buff medium to fine texture, organic profile 4"
4	8	fine carbonate, white with some sand quartz (lacustrine ?)
12	8	shale, red, silty, selenite, gypsum
20	10	shale, reddish brown, silty, slightly calcareous
30	12	shale, red, silty, with some medium crystalline limestone, red, laminae
42	23	gypsum, medium to fine crystalline, grayish white
65	10	gypsum, green, medium to fine crystalline
75	5	gypsum, moderate to fine crystalline, mottled gray-white with one thin bed of shale, red silty clayey
80	23	gypsum, medium crystalline, mottled gray to red
103	9	shale, red, clayey, silty
112	8	as above but with red gypsum laminae, medium crystalline
120	22	interbedded gypsum and limestone, gypsum is mottled gray and white, medium crystalline, with some coarse crystalline selenite limestone is gray, aphanitic
142	20	gypsum, white, medium crystalline, with some coarse selenite laminae
162	8	gypsum, gray, medium crystalline, with some reddish gray lenses on anhydrite laminae
170	10	as above, but no limestone laminae

Total Depth - 180'

Bailing results - ¼ gpm
Casing perforated - 140-160' below LSD
Water level - 145 ' below LSD
Measurement: March 1, 1979: Water level - 87' below LSD

Well 20.30.15.31; drilled November 1, 1978

Top	Thickness	Description
0	2	sand, fine, buff with organic concentration
2	20	sand, fine, buff heavy carbonate concentration (lacustrine deposit)
22	8	mud, very clayey, greenish gray, contains lacustrine fossils
30	10	as above, but reddish in color

Total Depth - 40'

Lithologic logs, continued

Well 20.30.15.31 continued

Casing perforated - 0-20' below LSD
Driller encountered water at 16' below LSD
The well flowed to surface about 8 gpm for about 5-10 minutes, after the casing was inserted, decreasing to 0
Bailer could not bring down
Measurement: December 28, 1979: Water level - 2.90' below LSD

Well 20.30.23.11; drilled November 4, 1978

Top	Thickness	Description
0	5	sand (aeolian), fine to medium, brownish-buff, 2' of organic profile
5	7	caliche, white, medium to strong nodule formation
12	8	shale, reddish brown, silty, with minor clayey laminae and laminae of silty texture with greenish gray inclusions, moderately calcareous
20	10	shale, red, clayey to silty, has greenish gray inclusions, has secondary calcite concentrated along bedding planes
30	10	shale, red, silty, has some greenish gray inclusions non-calcareous
40	8	as above, but has clayey laminae, slightly calcareous
48	12	shale brownish red, silty moderately calcareous
60	8	shale, reddish brown, has small greenish gray inclusions, very mildly calcareous
68	20	shale, brownish red, silty, has greenish-gray inclusions, has minor laminae of crystalline calcite (secondary) concentrated between bedding planes
88	12	as above, but no secondary calcite

Total Depth - 100'

Driller encountered moist sediments at 90' below LSD
Bailing test - estimate 5 gpm
Water level approximately 70' below LSD
Casing perforation - 80-100' below LSD
Measurement: March 1, 1979: Water level - 73' below LSD

Well 20.30.25.33; drilled October 30, 1978

Top	Thickness	Description
0	11	sandstone, buff
11	9	siltstone, sandy, dark red
20	10	as above, but pink
30	8	as above
38	37	shale, red, silty, more clayey than above

Lithologic logs, continued.

Well 20.30.25.33 continued

Top	Thickness	Description
75	9	shale, red, silty,fine grained, clayey interbedded with thin blue siltstone (brown)
84	6	shale, variegated red to light green, very silty with the red portions having more clay and less silt, and the green portions having more silt and small poorly rounded quartz grains
90	10	siltstone, mottled red and gray as above with less gray silt
100	10	shale, red, relative amounts of silt and clay vary between lamina
110	10	siltstone, mottled red and gray, very loosely consolidated, contains thin lenses of greenish gray siltstone
120	10	as above with more consolidation and no green silt lenses
130	10	silt, green h-buff, non-consolidated
140	30	shale, reddish brown, relative amounts of silt and clay vary between laminae, but mostly silty
170	10	as above, but with minor lenses of greenish-buff silt
180	20	shale, red, clayey with some silt
200	50	shale, red, silty
250	20	as above, but with small greenish-gray inclusions (reduction zones?)
270	10	shale, red, silty, fairly cohesive
280	10	shale, mottled red and gray, silty
290	20	as above, but with greenish-gray inclusions
310	30	as above but with thin laminae of satin spar gypsum (white) concentrated bedding planes in minute amounts

Total Depth - 340'

Casing perforated 320-340'
Bailing test showed water level about 323' below LSD
Yield ½ gpm
Measurement: February 27, 1979: Water level - 238' below LSD

Well 20.30.28.4; drilled October 27, 1978

Top	Thickness	Description
0	10	shale, clayey, red with abundant caliche formation (nodules 1 mm- 8 cm)
10	6	shale, silty, red, slightly calcareous due to small caliche content
16	14	shale, clayey, red, no caliche, very cohesive
30	30	shale, red, silty, some white inclusions (1 mm)
60	10	same as above, but more clayey, fewer inclusions
70	8	shale, red, silty, gray to white inclusions

Lithologic logs, continued.

Well 20.30.28.4 continued

Top	Thickness	Description
78	22	shale, mottled red to gray, variable silty to clayey gray inclusions increase in size to 8 mm
100	20	same as above, but more clayey, gray inclusions smaller (1 mm)
120	20	shale, clayey, lightish red, inclusions (gray), range 1 mm- 7 mm
140	10	same as above, fewer inclusions
150	10	shale, red, clayey, greenish-gray inclusions comprise 10% of volume
160	10	same as above with fewer and smaller inclusions
170	20	siltstone, clayey, mottled red and gray (inclusions gray, 2 mm in diameter)
190	12	gypsum, white to gray-white, fine crystalline
202	18	anhydrite, white to light gray, medium crystalline

Total Depth - 220'

Casing perforated 200-220'
Bailer 1/3 full per dip
Water level is 208.75 below LSD

Measurement: February 27, 1979: water level - 170' below LSD

Well 20.30.29.33; drilled November 1, 1978

Top	Thickness	Description
0	4	sand, brownish-buff, fine to medium texture organic weathering profile more than 2'
4	6	caliche, pinkish white, formed in nodules, relatively soft
10	10	sand and silt, reddish brown, with carbonate mineralization
20	10	shale, red, clayey, slightly calcareous
30	10	shale, red, very clayey, some green inclusion (reduction zones ?) mildly calcareous
40	20	as above, but with more silt and non-calcareous
60	10	shale, brownish red, silty, greenish gray inclusions
70	40	as above, but more clay
110	10	shale, brownish red, silty greenish gray inclusions
120	10	shale, reddish brown, clayey, has green inclusions, less cohesive than above
130	20	as above, but with some white inclusions(may be gypsum, non-calcareous)
140		encountered damp sediment

Total Depth - 150'
Hole scheduled for 100', sediments dry to 140' below LSD
Casing perforated - 130-150' below LSD
Bailing test - 6" of water in hole after casing set
Measurement: February 28, 1979: Water level - 134.0' below LSD

Lithologic logs, continued.

Well 20.31. 2.34; drilled November 13, 1978

Top	Thickness	Description
0	6	sand, buff, medium-fine texture (aeolian)
6	6	caliche, white medium formation
12	8	sand, brownish-buff medium-fine texture, secondary carbonate cement
20	10	shale, reddish brown, clayey
30	10	shale, brown, silty, has a bed of green silty shale
40	10	shale, reddish brown, silty
50	10	shale, brown,silty, has greenish gray inclusions
60	10	shale, maroon, silty, has clayey laminae, greenish gray laminae
70	10	shale, brown, silty
80	15	shale, maroon-brown, silty
95	8	limestone, mottled gray-white, red, fine crystalline
103	7	shale, brown, clayey-silty greenish gray inclusions
110	20	shale, brown, clayey
130	10	as above, but with minor laminae of green silty shale
140	10	shale, reddish brown, silty-sandy, has a bed of green silty shale, slightly moist
150	10	sandstone, brown, medium-fine texture, calcareous cement

Total Depth - 160'

Bailing test - estimates less than 1 gpm
Encountered moist sediments - 145' below LSD
Water level - 150' below LSD
Measurement: January 19, 1979: Water level - 137.0' below LSD

Well 20.31.17.33; drilled November 14, 1978

Top	Thickness	Description
0	12	caliche, white-gray medium to strong formation
12	9	sand, brown, medium-fine texture, calcareous cement
21	11	shale, reddish brown silty
32	8	shale, brown, silty with clayey laminae
40	9	shale, brownish red, clayey, with silty laminae and greenish gray silty laminae
49	11	shale, brown, clayey, has greenish gray laminae and is fissile with micaceous partings
60	10	shale, reddish brown, clayey
70	18	shale, dark brown, very clayey, has chloritic partings, has laminae of green clayey shale
88	20	shale, brown, silty, has greenish gray inclusions
108	20	as above, but more clay
128	20	as above, but has laminae of greenish-gray silty-clayey shale
148	12	shale, reddish brown, silty, has clayey laminae
160	10	as above, but no clay
170	10	shale, brown, silty, has clayey laminae, has green clayey laminae, has fine crystalline gray anhydrite laminae
180	10	shale, reddish brown, silty has some green inclusions has some laminae of clear satin spar gypsum

Lithologic logs, continued.

Well 20.31.17.33 continued

Top	Thickness	Description
190	10	shale, reddish brown, clayey, has some fine crystalline gray anhydrite
200	10	shale, reddish brown, silty, has greenish gray inclusions, has some thin clear satin spar gypsum
210	20	as above, but has some gray fine crystalline anhydrite
230	10	as above, but has some greenish gray inclusions and some clayey laminae

Total Depth - 240'

Bailing results - estimates ¼ gpm
Casing perforations - 220-240' below LSD

Measurement: March 1, 1979: Water level - 227.0' below LSD

Well 20.31.27.24; drilled November 1, 1978

Top	Thickness	Description
0	4	sand, brownish-buff, fine to medium
4	8	strong caliche formation forms thick continuous bed
12	16	sand, dark brown, medium texture, slightly calcareous from overlying carbonate mineralization
28	12	as above, but less calcareous and finer texture
40	11	shale, dark reddish brown, very clayey
51	10	sandstone, greenish gray, fine to medium texture, with a lens of very clayey green shale
61	10	as above, but with lenses of mottled brown and green fine sandstone
71	9	shale, reddish brown, texture mostly coarse silt but with lenses of very clayey brown shale
80	10	as above, but with no clayey lenses
90	20	shale, silty, reddish brown. minor clayey laminae
110	14	shale, brownish red, silty with clayey laminae
124	7	shale, reddish brown, clayey, slightly silty
131	10	shale, reddish brown, silty
141	9	shale, reddish brown, silty with some clayey laminae and some greenish gray silty laminae

Total Depth - 150'

Casing perforated - 130-150' below LSD
Bailing test - 3-4' water in hole after casing placement-bailer removed it in 4 trips (producing less than 1 gpm)
Measurement: February 28, 1979: Water level - 114' below LSD

Lithologic logs, continued.

Well 20.31.30.44; drilled October 31, 1978

Top	Thickness	Description
0	10	sand, caliche, very strong, constituting major volume of sample, buff
10	10	sandstone, reddish brown, calcareous, calcite cement from strong caliche profile above
20	7	sandstone, fine to medium texture, mottled brownish red to gray (gray grains inside red) non- calcareous
27	21	as above, but containing minor lenses of red silty shale and greenish-white siltstone
48	3	shale, silty, bluish-green
51	8	resumes characteristics of silty sandstone, see above
59	11	dolomitic sandstone, silty, mottled brown to greenish gray; thin lenses show vigorous effervescense
70	10	silt, reddish brown, unconsolidated except minor lenses which have some clay and are darker in color, slightly calcareous
80	20	siltstone, reddish brown, slightly calcareous, moderate consolidation
100	10	shale, red, silty, with some minor laminae of greenish gray shale (silty)
110	8	shale, mottled brown to gray, silty with notable laminae of dark reddish brown zones of very clayey composition
118	17	silt, reddish brown, very loosely consolidated
135	8	shale, brown, very clayey
143	7	shale grayish, green, clayey, loosely consolidated in silt strata
150	50	shale, reddish brown, very clayey
200	10	shale, dark brown subequal amounts of silt and clay with some thin layers of green claystone
210	10	shale, brown, silty
220	10	as above, but containing minor lenses of green siltstone
230	10	shale, brown, silty
240	10	as above, but with minor lenses of green siltstone
250	20	shale reddish brown, clayey thin lenses of green siltstone, traces of satin spar gypsum concentrated in bedding (white to clear)
270	10	as above, but with traces of selinite gypsum (clear)
280	20	shale, reddish brown, clayey, laminae of satin spar gypsum, has a small number of limestone fragments (white)
300	8	shale, red, silty has thickish laminae of satin spar gypsum and minor amounts of greenish gray anhydrite, fine crystalline
308	12	shale, brownish red, clayey small amounts of greenish gray anhydrite

Lithologic logs, continued.

Well 20.31.30.44 continued

Total Depth - 320'

Casing perforated - 300-320' below LSD
Water standing in well upon completion - 3-4' (316' below LSD)
Bailing test - negilgible
Measurement: February 27, 1979: Water level - 228' below LSD

Well 20.32.17.13; drilled November 8, 1978

Top	Thickness	Description
0	3	sand, fine buff-brown aeolian, 3" organics
3	10	calcareous ooze, white (lacustrine)
13	7	as above, but with sand laminae, calcified (caliche)
20	15	sandstone, brown, fine texture, loosely consolidated
35	5	shale, brown, sandy, silty, has gypsum, selenite and fine crystalline (gray)
40	10	shale, reddish brown, clayey with silt, has green clayey laminae
50	10	shale, reddish brown, silty with clay, has green silty laminae
60	23	as above, but reddish color
83	7	shale, brown, silty, has greenish-gray silty laminae
90	10	shale, brown, sand (fine)

Total Depth - 100'

Casing perforated - 20-40' below LSD
Bailing test - estimates 15 gpm
Encountered water at 18' below LSD
Water very salty (maybe with potassium)

Measurement: February 28, 1979; Water level - 9' below LSD

Well 20.32.22.33; drilled November 8, 1978

Top	Thickness	Description
0	3	sand, brownish-buff, medium-fine texture (aeolian) 6" organic profile
3	9	caliche, white, medium to strong formation
12	18	sand, pinkish buff, medium-fine texture, calcareous cement
30	10	shale, brown, clayey with laminae of greenish-gray medium crystalline, anhydrite
40	20	shale, brown, silty
60	10	shale, red-brown, silty, clayey, has minor amount thin laminae of green silty shale
70	10	as above, but no green shale
80	20	shale, red-brown, clayey with laminae of green clayey-silty shale

Lithologic logs, continued.

Well 20.32.22.33 continued

Top	Thickness	Description
100	10	as above, but no green shale
110	30	shale, brown, silty
140	10	shale, brown-silty, clayey, has laminae of gray silty shale
150	10	shale, brown, clayey, has laminae of greenish gray silty shale
160	10	shale, reddish brown, silty-clayey, has greenish gray inclusions, has small nodules of maroon limestone

Total Depth - 170'

Driller encountered water at 35' (probably perched brine from Laguna Toston)
Casing perforated - 150-179' below LSD
Bailing results - estimates 12-15 gpm
Tastes fresh
Measurement: February 28, 1979: Water level - 30' below LSD

Well 20.32.31.13; drilled November 8, 1978

Top	Thickness	Description
0	10	sand, buff medium to fine texture, moderate caliche formation
10	13	sand, brown-buff, fine to medium texture, leached carbonate
23	13	shale, reddish brown, silty with clayey laminae
36	4	shale, greenish gray, silty, sandy
40	30	shale, brown, silty-clayey shale, reddish brown
70	10	silty-clayey, has a bed of greenish-gray siltstone
80	20	shale, brown, clayey
100	20	as above, but more silt
120	30	shale, brown, clayey, interbedded with limestone, brown, fine crystalline
150	10	shale, brown, clayey-silty
160	10	as above, but reddish brown
170	10	shale, brown, silty-clayey, has zones of superior cementation along bedding, probably calcite
180	10	shale, brown, clayey, fairly cohesive from cementation
190	10	shale, brown, varigated clayey to silty, has greenish gray inclusions
200	20	shale, greenish to gray, silty, interbedded with brown silty shale
220	20	shale, reddish brown silty zones of calcite cementation along bedding
240	10	shale, reddish brown, clayey

Lithologic logs, continued.

Well 20.32.31.13 continued

Total Depth - 250'

Water level-drilled dry, never encountered moist sediments
Casing perforated - 230-250' below LSD
Bailing results - bailing showed about 8' water in hole (probably residual from drilling) - dry ; DTW 135.12' March 15, 1979

Well 21.29. 2.14; drilled November 16, 1978

Top	Thickness	Description
0	5	sand, brown-buff, medium-fine texture (aeolian) has 3-6" of organics
5	15	caliche, white, formed in sand, medium formation
20	10	sand, brownish buff, medium-fine texture, sub-angular to rounded quartz grains
30	10	as above, but has some pebbles (quartz) 6 mm in diameter
40	20	as above, but pebbles increase in size to 1.5 cm
60	10	sand, reddish brown medium-fine small quartz pebbles
70	10	shale, red clayey
80	20	shale, red, clayey-silty, has laminae of greenish gray clayey shale and greenish gray inclusions
100	20	as above, but no inclusions green-gray laminae
120	10	shale, red, silty with clayey laminae
130	20	as above, but has greenish gray inclusions
150	10	shale, brownish-red, silty, clayey
160	10	shale, reddish brown, clayey, has greenish gray inclusions
170	10	as above, but silty
180	10	shale, brown, clayey, has greenish gray inclusions
190	20	as above, but reddish brown and silty
210	10	shale, brown, silty, has same greenish gray inclusions
220	10	as above, but very loosely consolidated
230	10	shale, red, silty
240	20	as above, but has some clay, has greenish gray inclusions
260	34	gypsum, light gray, fine crystalline
294	21	shale, red, silty-clayey, has greenish gray inclusions
315	25	gypsum, white, aphanitic, has laminae of silty red shale
340	10	as above, but gypsum is light gray
350	16	above, but no shale
366	24	shale, light red, silty, has laminae of gypsum, light gray to white, fine crystalline, gypsum in small rounded fragments, well mixed
390	40	as above, but redder in color (mixture of red clayey shale and gypsum)
430	30	mixture of red shale, silty-clayey, gypsum, soft dark gray, fine crystalline, also has selenite gypsum in small amounts

Lithologic logs, continued.

Well 21.29.2.14 continued

Total Depth - 460'

Bailing results - estimates more than 20 gpm
Casing perforated - 420-460' below LSD
Water level - 350' below LSD
Water tastes salty

Measurement: March 1, 1979: Water level 273.0' below LSD

Well 21.31. 3.22; drilled November 9, 1978

Top	Thickness	Description
0	18	caliche, white, moderate to strong formation
18	12	sand, brown-buff, medium-fine texture, calcareous cement
30	10	shale, buff-red, silty, calcareous laminae
40	10	shale, red, clayey with some silt
50	10	shale, mottled red, greenish gray, has sandy laminae but mostly silt
60	10	shale, brown, silty, with clayey laminae, has greenish gray inclusions
70	10	shale, reddish, brown, silty, has good cement, some laminae (calcite) (these laminae are gray-red)
80	10	as above, but subequal amounts of silt and clay
90	10	shale, red, silty, ahs clayey laminae
100	20	shale, brownish red, silty, has laminae with calcite cement
120	10	as above, but more calcite zones (mineralized with crystalline calcite)
130	10	shale, brownish red, silty
140	10	as above, but has clayey laminae
150	10	shale, brownish red, silty, has calcite mineralized laminae
160	10	shale, red, clayey, has laminae of silty greenish gray shale
170	10	shale, reddish brown, silty
180	10	as above, but has laminae of greenish gray shale
190	10	shale, brownish red, subequal amounts of silt and clay, has greenish gray laminae, silty

Total Depth - 200'

Driller encountered water at 150' below LSD
Casing perforated 140-160' below LSD
Bailing results - estimates 8 gpm
Water level on completion - 128' below LSD
Measurement: February 28, 1979: Water level - 142' below LSD

Lithologic logs, continued.

Well 21.31.15.33; drilled November 13, 1978

Top	Thickness	Description
0	20	shale, brown, silty with some sand
20	10	shale, brownish red, subequal amounts of silt and clay
30	10	shale, brown, silty, has clayey laminae
40	10	shale, brown, silty, has chlorite in some laminae
50	10	shale, reddish brown, silty, with clayey laminae, very fissile, with chlorite causing fissility, has greenish-gray clayey laminae
60	7	as above, but has laminae of reddish brown, fine crystalline limestone
67	13	shale, reddish brown, clayey, has minor laminae of green clayey shale
80	10	shale, brown, clayey-silty, has laminae of mottled red and white, medium crystalline limestone and laminae of clear satin spar gypsum
90	10	shale, brown, clayey, has laminae of gray, medium crystalline limestone and laminae of clear satin spar gypsum, shale is fissile with chlorite partings
100	10	shale, brown, clayey-silty, has satin spar laminae and chloritic partings, green inclusions
110	10	shale, reddish brown, silty
120	10	as above, but has clayey laminae and green inclusions
130	30	shale, brown, clayey, has greenish gray laminae
160	10	shale, reddish brown clayey-silty, has greenish gray inclusions
170	10	as above, but no inclusions
180	22	shale, brown clayey, has greenish gray inclusions
202	11	sandstone, buff, medium texture, well rounded quartz grains
213	7	shale, reddish brown, silty
220	10	as above, but with clayey laminae and greenish gray laminae
230	40	shale, reddish brown, silty, has greenish gray inclusions
270	20	as above, but with minor laminae of gray fine crystalline anhydrite
290	10	shale, brownish red, silty, has greenish gray inclusions
300	10	shale, reddish brown, silty with a clayey laminae
310	50	as above, but no clay and has greenish gray inclusions

Total Depth - 360'

Casing perforated
Bailing results - negligible
Water Level - 352' below LSD
Dry, March 15, 1979

Lithologic logs, continued.

Well 23.28. 1.11; drilled October 25, 1978

Top	Thickness	Description
0	31	siltstone, clayey, orange-red, calcareous, some fine sand, soft, weakly cemented
31	32	anhydrite, or light tan shale, white to buff, very fine crystalline texture, slightly calcareous no weathering or signs of alteration, uniform creamy smooth texture, almost looks like lithographic limestone but not calcareous enough
63	7	shale, very clayey, dark red, no silt or sand
70	10	shale, very clayey, dark red, no silt or sand
80	8	shale, very clayey, dark red, no silt or sand, with thin interbeds of crystalline gypsum
88	14	shale, very clayey, dark red, no silt or sand, with crystalline gypsum interbeds
102	8	siltstone, gray, very fine grit, with some crystalline gypsum pebbles in sample
110	12	shale, gray, some silt becoming clayey downward
122	7	siltstone, gray, soft, slightly clayey but not as much as above
129	7	siltstone, gray, siltier than above, hard, with few gypsum pebbles in sample, not clayey at all
136	9	shale, red, very clayey and soft, no grit, sample contains some gray siltstone increasing downward, interbedded with red shale
145	7	siltstone, red and gray, probably interbedded with red and gray, moderate amounts of red clay
152	8	shale, gray to dark gray, not silty, fine texture, non-chalcareous
160	10	shale, red, very clayey, contains a small amount of gray shale fragments
170	10	as above but with more gray shale fragments
180	10	shale, red, very clayey, interbedded with significant amounts of gypsum, mottled, black and white and gray, red crystalline
190	10	shale, brown to gray, very clayey, interbedded with thin laminae of hard non-clayey gray shale
200	15	shale, reddish brown, very clayey, contains some fine crystalline gypsum, mottled gray to white
215	6	shale, red to brown, very clayey, contains gypsum fragments increasing downward
221	8	gypsum, clear to white, mottled gray with some red clayey shale, predominately gypsum
229	10	gypsum, medium crystalline, mottled white and clear to gray with some red, with a small amount of red clayey shale interbedded
239	11	same as above, but with a very small amount of greenish gray silty shale, thin bedded and

Lithologic logs, continued.

Well 21-29, T.11S. drilled October 25, 1978

ion	Thickness	Description
0	31	siltstone, clayey, cherty, red, calcareous, some fine sand, soft, mostly cemented
31	32	mudstone, pn light tan shale, white to buff, very fine crystalline texture, slightly calcareous no weathering or signs of alteration, pretty creamy smooth texture, almost looks like lithoporphic limestone but not calcareous enough
63	7	shale, very clayey, dark red, no silt or sand
70	10	shale, very clayey, dark red, no silt or sand
80	8	shale, very clayey, dark red, no silt or sand, with thin inserts of crystalline gypsum
88	14	shale, very clayey, dark red, no silt or sand, with crystalline gypsum interbed.
102	8	siltstone, gray, very fine grit, with some crystalline gypsum nodules in sample
110	12	shale, gray, some silt becoming clayey downward
122	7	siltstone, gray, soft, slightly clayey but not as much as above
129	7	siltstone, gray, slitter than above, hard, with few gypsum pebbles in sample, not clayey at all
136	9	shale, red, very clayey and soft, no grit, sample contains some gray siltstone increasing downward, interbedded with red shale
145	7	siltstone, red and gray, probably interbedded with red and gray, moderate amounts of red clay
152	8	shale, gray to dark gray, not silty, fine texture, non-calcareous
160	10	shale, red, very clayey, contains a small amount of gray shale fragments
170	10	as above but with more gray shale fragments
180	10	shale, red, very clayey, interbedded with significant amounts of gypsum, mottled, black and white and gray, red crystalline
190	10	shale, brown to gray, very clayey, interbedded with thin lamina of hard non-clayey, gray shale
200	15	shale, reddish brown, very clayey, contains some fine crystalline gypsum, mottled gray to white
215	6	shale, red to brown, very clayey, contains gypsum fragments increasing downward
221	8	gypsum, clear to white, mottled gray with some red clayey shale, predominately gypsum
229	10	gypsum, medium crystalline, mottled white and clear to gray with some red, with a small amount of red clayey shale interbedded
239	11	same as above, but with a very small amount of green-gray silty shale, thin bedded and

Lithologic logs, continued.

Well 23.28.1.11 continued

Top	Thickness	Description
		moderately cohesive
250	10	shale, red, clayey, interbedded with gypsum, white to pink, medium crystalline with some dark gray shale interbedded
260	10	as above but with brown very clayey shale
270	10	gypsum, medium to crystalline clear to dark gray with some red gypsum
280	10	gypsum, white to gray with broad flat flakes, with brown clayey shale and some dark gray shale
290	10	anhydrite, light gray crystalline with some brownish pink shale, very clayey

Total Depth - 300'
Lost circulation at 260', and at 70', but came back quickly; driller suspects cavity at 260-270'

Bail test - 4 pm October 26, 1978 - Dry
Perforated 260-280'
Measurement: February 27, 1979: Water level-161' below LSD

Well 23.29.18.14; drilled November 17, 1978

Top	Thickness	Description
0	4	sand, brownish-buff, fine texture (aeolian) organics-4"
4	6	clay, buff-flesh, has some gypsum, medium crystalline selenite pebbles
10	20	sand and gravel: sand-medium fine texture, buff; gravel-less than 3 cm in diameter, assorted lithologies; quartzite limestone, has a lot of interstitial calcite
30	5	as above but has more sand

Total Depth - 35'

Casing penetrated - 15-35' below LSD
Bailing results - 15-20 gpm
Water level - about 6' below LSD
Water tastes salty

Measurement: January 4, 1979: Water level - 7.1' below LSD

Lithologic logs, continued.

Well 23.29.20.33; drilled October 25, 1978

Top	Thickness	Description
0	11	caliche, white to tan, massive with some black chert pebbles, and quartz pebbles
11	13	siltstone, yellow, very fine grained, calcareous, heavily oxidized and has abundant orange staining, loosely cemented probably calcite cement, soft
24	8	silty shale, light buff, contains approximately 30% pebbles of limestone and chert (may be residuals from next higher unit)
32	11	limey siltstone, mostly silt, medium buff, thin bedded (very calcareous)
43	7	gypsum, silty shale, appears much like siltstone, slightly crystalline, tan, very soft, non-calcareous
50	10	limestone, orange, finely crystalline, aboundant black spotting, fizzes strongly, hard

Total Depth 60'

Water encountered at 50'
Perforated 40-60'
WL upon completion 27'
Bailing 15 gpm did not lower
Brine

Measurement: February 27, 1979: Water level - 24' below LSD

Well 23.29.26.12; drilled October 24, 1978

Top	Thickness	Description
0	10	sand (windblown), medium red, fine to medium grained, silty to clayey
10	10	sand, pale medium red, fine to medium grained, silty to clayey
20	8	shale, reddish brown, medium hard
28	12	limestone, mottled, yellowish brown, medium crystalline
40	11	shale, red, soft
51	21	anhydrite (or hard shale), medium grained, very fine crystalline
72	9	shale, dark gray
81	16	shale, variegated, red and gray
97	12	siltstone, yellowish green
109	10	shale, red, silty
119	41	anhydrite (or hard, tan shale), with thin bedded gray shale

Lithologic logs, concluded.

Well 23.29.26.12 continued

Total Depth — perforated 140-160; bail test did not produce one full bailer, very slow recovery

Measurement: October 27, 1978: Water level - 155.4' below LSD
February 27, 1979: Water level - 108' below LSD

Well 23.29.28.41; drilled October 24, 1978

Top	Thickness	Description
0	10	light gray limestone, aphanitic with amber calcite vug fillings
10	10	light buff limestone, aphanitic
20	8	amber limestone, medium crystalline with pink streaks
28	18	shale, variegated red and gray, slightly silty, very clayey
46	4	gypsum, pinkish white, medium crystalline
50	15	shale, very soft, red with thin lenses of blue-gray shale interbedded, moderately silty, medium clayey
65	6	gypsum, white, medium crystalline
71	7	shale, interbedded red and gray, calcareous with some gypsum (gray)
78	6	gypsum, massive, medium crystalline, white, interbedded with siltstone, dark gray, slightly calcareous
84	TD	siltstone, gray, thin bedded

Total Depth - 100'
Casing perforated - 50-60'
70-80'

Bailed at 15-20 gpm, no drawdown effect
Water tasted brine
Water encountered at 55'
WL upon completion 40'

2 aquifers most probably:
55' - water encountered; approximate flow 1.5 gpm
75-80' - water encountered; approximate flow 5 gpm

Measurement: February 27, 1979: Water level 40' below LSD

CHEMICAL WATER ANALYSES

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 19.30.33.31 Chemist Joan M Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	315.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	74.5	
Manganese		
Mercury		
Nickel		
Potassium	29.	
Silver		
Sodium	160.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	<0.05	
Bromide		
Carbonate		
Chloride	227.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	1750.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	<0.02	

Acidity	ppm
Alkalinity	ppm
BOD	ppm
Chlorine	ppm
COD	ppm
Color	PCU
Conductance	µmho/cm
Dissolved O_2	ppm
Hardness	ppm
H_2S	ppm
Hydrazine	ppm
Odor	T.O.
pH	
Phenols	ppm
Silica	ppm
Solids (Tot.)	ppm
Solids (Tot. Diss.)	3320. ppm
Solids (Tot. Susp.)	ppm
Solids ( )	ppm
Surfactant	ppm
Turbidity	JTU
Volatile Acids	ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Raad NE

Appearance and Data 20.30.15.31 Chemist Joan M Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	310.	
Chromium (T)	0.01	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	286.	
Manganese		
Mercury		
Nickel		
Potassium	95.	
Silver		
Sodium	1525.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	1.7	
Bromide		
Carbonate		
Chloride	305.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	3125.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	0.01	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		μho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	10,260.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

Albuquerque Analytical, Inc.

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[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 20.30.23.11 Chemist Joan M Hoover

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	230.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	129.	
Manganese		
Mercury		
Nickel		
Potassium	6.42	
Silver		
Sodium	280.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	<0.05	
Bromide		
Carbonate		
Chloride	85.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	800.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	<0.02	

Acidity	ppm
Alkalinity	ppm
BOD	ppm
Chlorine	ppm
COD	ppm
Color	PCU
Conductance	μmho/cm
Dissolved O_2	ppm
Hardness	ppm
H_2S	ppm
Hydrazine	ppm
Odor	T.O.
pH	
Phenols	ppm
Silica	ppm
Solids (Tot.)	ppm
Solids (Tot. Diss.)	4016. ppm
Solids (Tot. Susp.)	ppm
Solids ( )	ppm
Surfactant	ppm
Turbidity	JTU
Volatile Acids	ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 20.30.23.11 Chemist Joanne Hoover

	mg/l	meq/l		mg/l	meq/l		
Aluminum			Beryllium (BeO_3^-)			Acidity	ppm
Ammonium			Bicarbonate			Alkalinity	ppm
Arsenic			Boron (BO_2^-)	<0.05		BOD	ppm
Barium			Bromide			Chlorine	ppm
Cadmium			Carbonate			COD	ppm
Calcium	230.		Chloride	85.		Color	PCU
Chromium (T)	<0.02		Cyanide			Conductance	µmho/cm
Cobalt			Fluoride			Dissolved O_2	ppm
Copper			Hydroxide			Hardness	ppm
Gold			Iodide			H_2S	ppm
Iron			Molybdenum (MoO_4^-)			Hydrazine	ppm
Lead			Nitrate			Odor	T.O.
Lithium			Nitrite			pH	
Magnesium	129.		Phosphate (Tot.)			Phenols	ppm
Manganese			Phosphate (Meta)			Silica	ppm
Mercury			Phosphate (Ortho)			Solids (Tot.)	ppm
Nickel			Selenium (SeO_4^-)			Solids (Tot. Diss.)	4016. ppm
Potassium	6.42		Sulfate	800.		Solids (Tot. Susp.)	ppm
Silver			Sulfite			Solids ( )	ppm
Sodium	280.		Tellurium (TeO_3^-)			Surfactant	ppm
Uranium (U_3O_8)			Vanadium			Turbidity	JTU
Zinc			chromium + 6	<0.02		Volatile Acids	ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 20.32.17.13 Chemist Jan M Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	1320.	
Chromium (T)	0.15	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	2900.	
Manganese		
Mercury		
Nickel		
Potassium	4615.	
Silver		
Sodium	24750.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	1.3	
Bromide		
Carbonate		
Chloride	16,980.6 *	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	3750.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	0.14	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		µhos/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	172,828.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

* Gravimetric determination

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 20.32.22.33 Chemist Joan M. Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	105.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	92.	
Manganese		
Mercury		
Nickel		
Potassium	33.5	
Silver		
Sodium	325.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	0.3	
Bromide		
Carbonate		
Chloride	75.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	550.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	<0.02	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		μmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	3136.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Raod NE

Appearance and Data PUE WELL # 1 ; 21.29.25. 423a Chemist Joan M. Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	260.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	132.5	
Manganese		
Mercury		
Nickel		
Potassium	8.2	
Silver		
Sodium	175.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	<0.05	
Bromide		
Carbonate		
Chloride	77.5	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	800	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium +6	<0.02	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		µmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	3836.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data PUE WELL # 2 ; 21.29.25.423b Chemist Joan M Glover

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	305.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	150.	
Manganese		
Mercury		
Nickel		
Potassium	6.21	
Silver		
Sodium	265.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium ($BeO_3^=$)		
Bicarbonate		
Boron (BO_2^-)	<0.05	
Bromide		
Carbonate		
Chloride	70.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum ($MoO_4^=$)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium ($SeO_4^=$)		
Sulfate	875.	
Sulfite		
Tellurium ($TeO_3^=$)		
Vanadium		
chromium + 6	<0.02	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		µmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	4400.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 21.31.3.22 Chemist Jean M. Brown

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	19.9	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	17.5	
Manganese		
Mercury		
Nickel		
Potassium	3.55	
Silver		
Sodium	19.6	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium ($BeO_3^=$)		
Bicarbonate		
Boron (BO_2^-)	<0.05	
Bromide		
Carbonate		
Chloride	18.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum ($MoO_4^=$)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium ($SeO_4^=$)		
Sulfate	20.	
Sulfite		
Tellurium ($TeO_3^=$)		
Vanadium		
chromium + 6	<0.02	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		µmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	424.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 23.29.18.14 Chemist Jean M. Hoover

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	355.	
Chromium (T)	<0.02	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	2350.	
Manganese		
Mercury		
Nickel		
Potassium	262.	
Silver		
Sodium	10375.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate	1.7	
Boron (BO_2^-)		
Bromide		
Carbonate		
Chloride	14,647.1 *	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	5000.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	<0.02	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		μmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	55,876.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

* Gravimetric determination

Albuquerque Analytical, Inc.

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. 8804

Rec'd. Feb. 2, 1979

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data 23.29.20.33 Chemist

	mg/l	meq/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	460.	
Chromium (T)	0.025	
Cobalt		
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	2337.5	
Manganese		
Mercury		
Nickel		
Potassium	3590.	
Silver		
Sodium	25125.	
Uranium (U_3O_8)		
Zinc		

	mg/l	meq/l
Beryllium (BeO_3^-)		
Bicarbonate	3.5	
Boron (BO_2^-)		
Bromide		
Carbonate		
Chloride	10,715. *	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	4375.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		
chromium + 6	0.025	

Acidity		ppm
Alkalinity		ppm
BOD		ppm
Chlorine		ppm
COD		ppm
Color		PCU
Conductance		µmho/cm
Dissolved O_2		ppm
Hardness		ppm
H_2S		ppm
Hydrazine		ppm
Odor		T.O.
pH		
Phenols		ppm
Silica		ppm
Solids (Tot.)		ppm
Solids (Tot. Diss.)	153,404.	ppm
Solids (Tot. Susp.)		ppm
Solids ( )		ppm
Surfactant		ppm
Turbidity		JTU
Volatile Acids		ppm

* Gravimetric Determination

Environmental Biochemists

[505] 266-9106
[505] 294-6310 Nights

4115 Silver S.E.
Albuquerque, N.M. 87108

No. _____

Rec'd. Dec. 28, 1978

WATER ANALYSIS

Owner Geohydrology & Associates Address 3225 Candelaria Road NE

Appearance and Data test #1 23.29.28.41 Chemist Joan M. Grover

	mg/l	meg/l
Aluminum		
Ammonium		
Arsenic		
Barium		
Cadmium		
Calcium	202.25	
Chromium (CrO_3^-)	0.02	
Copper		
Gold		
Iron		
Lead		
Lithium		
Magnesium	684.	
Manganese		
Mercury		
Potassium	4,150.	
Silver		
Sodium	68,750.	
Uranium (U_3O_8)		
Zinc		
Anion/Cation = ___%		

	mg/l	meg/l
Beryllium (BeO_3^-)		
Bicarbonate		
Boron (BO_2^-)	20.0	
Bromide		
Carbonate		
Chloride	142,500.	
Cyanide		
Fluoride		
Hydroxide		
Iodide		
Molybdenum (MoO_4^-)		
Nitrate		
Nitrite		
Phosphate (Tot.)		
Phosphate (Meta)		
Phosphate (Ortho)		
Selenium (SeO_4^-)		
Sulfate	3,750.	
Sulfite		
Tellurium (TeO_3^-)		
Vanadium		

Hexavalent Chromium (+6) 0.058ppm

Alkalinity	ppm
BOD	ppm
Chlorine	ppm
COD	ppm
Color	PCU
Conductance	μho/cm
Dissolved O_2	ppm
Hardners	ppm
H_2S	ppm
Hydrazine	ppm
Odor	T.O.
pH	
Phenols	ppm
Silica	ppm
Solids (Tot.)	ppm
Solids (Diss.) (TOT) 283,492.	ppm
Solids (Susp.)	ppm
Solids ( )	ppm
Surfactant	ppm
Turbidity	JTU
Volatile Acids	ppm

RECORDS OF WELLS AND TEST HOLES IN PROJECT AREA

RECORDS OF WELLS AND TEST HOLES IN PROJECT AREA

Formations: T, Tertiary rocks; Cplm, Capitan Limestone; Dckm, Dockum Group; Tnsl, Tansill Formation; Clbd, Carlsbad; Ckbf, Chalk bluff; others as in Table 5.
tc, top of casing

Location	Well Status	Altitude (feet)	Depth of Well (ft)	Depth to Water (ft)	Aquifer	Date of Measurement
18.29.24.142	Windmill	3,436		156.44		10/18/77
24.233	Windmill	3,436		160.20	Tr undiff.	04/08/71
30.21.420	Open cased hole	3,495		266.48		12/09/65
22.222	Open cased hole	3,430		239.26	T	04/08/71
26.414	Stock	3,430	223.0	201.67	T	12/14/77
31.323	Observation	3,370	161.0	160.21		03/14/79
32.324	Windmill	3,380		161.28		04/08/71
31.35.313	Domestic	3,631	300	261.08	T	04/05/71
32.20.133	Domestic	3,740	270.0	179.35	T	02/23/71
19.28. 5.211	Windmill	3,547	160.0	150.62	Pr	01/28/71
13.214	Stock	3,369	160	153.02	Pr	02/01/71
18.11	Stock	3,490	93	74		03/ /72
18.121	Stock	3,505	100	88.31	Pr	01/28/71
19.11	Stock	3,495	100	91		03/ /71
24.322	Windmill	3,351		130.10	Pr	02/01/71
33.214	Windmill	3,545	125	121.07	Pr	01/28/71
36.432	Windmill	3,292	87	71.75	Pr	02/01/71
29.10.432	Stock	3,370	153.0	145.84	Pr	02/01/71
13.412	Open cased hole	3,311		110.64	Pr	02/01/71
20.241	Windmill	3,305		66.87	Pr	02/01/71
23.231	Windmill	3,268	85.0	68.91	Pr	02/01/71
25.441	Stock	3,322	125.7	64.03		10/18/77
30. 3.44	BLM test well	3,399.98 tc	220	144.84 tc		03/14/79

Records of wells and test holes in project area, continued.

Location	Well Status	Altitude (feet)	Depth of Well (ft.)	Depth to Water (ft.)	Aquifer	Date of Measurement
19.30. 5.32	BLM test well	3,345.19 tc	170	141.31 tc	Qvf	03/14/79
17.441	Stock	3,329		142.70	Tr undiff	02/01/71
24.133	BLM test well	3,262.08 tc	70	52.13 tc	Prfn,PTrdl	03/07/79
25.112	None		22.98			12/16/77
25.123	Observation	3,245	42	21.59		03/14/79
33.31	BLM test well	3,216.49 tc	50	20.22 tc	Prfn	03/15/79
35.23	BLM test well	3,265.59 tc	100	79.65 tc	PTrdl	
31.27.211	Open cased hole	3,473		142.71	Tr undiff	02/01/71
28.333	Domestic/Stock	3,483	200.0	186.87		12/15/77
28.334	Stock	3,442	180	108.21	Tr undiff	02/01/71
32.29.32	BLM test well	3,549.61 tc	100	dry		03/15/79
20.27.14.42	Stock	3,315	81	66		05/ /72
29. 3.434	Stock, windmill	3,300	95.8	88.34		12/15/77
16.434	Abandoned	3,259	103.1	52.28		12/15/77
20.311	Stock	3,246	62.8	43.76		12/15/77
25.33	BLM test well	3,288.18	180	87.27	Prfn	03/08/79
30. 7.112	Observation	3,227	42.8	28.69		03/15/79
15.31	BLM test well	3,198.95 tc	40	3.03 tc	Qp	03/15/79
17.433	Abandoned	3,215	66.0	26.35		12/15/77
20.2	Observation	3,200		12.88		03/15/79
21.434	Industrial	3,375	335	150		01/16/74
23.11	BLM test well	3,275.43 tc	100	72.95	PTrdl	03/15/79
25.33	BLM test well	3,513.28 tc	340	244.12		03/15/79
28.44	BLM test well	3,373.05 tc	170	173.24	PTrdl	03/14/79
29.33	BLM test well	3,333.30 tc		134.63	Trdl	03/14/79
31.23	Observation	3,298		99.86		03/15/79

Records of wells and test holes in project area, continued.

Location	Well Status	Altitude (feet)	Depth of Well (ft.)	Depth to Water (ft.)	Aquifer	Date of Measurement
20.30.32.341		3,365		327.32	Cplm	09/ /74
32.43	Observation	3,340		175.0		03/15/79
31. 2.34	BLM test well	3,482.89 tc	160	136.545 tc	Tr undiff	03/14/79
13.42	Stock, Abandoned	3,427	32.5	1.1		10/05/77
16.24	Stock	3,458	110.0	61.0	Dckm ?	10/05/77
17.33	BLM test well	3,497.05 tc	240	225.46 tc		03/15/79
27.24	BLM test well	3,530.23 tc	150	114.43 tc	Tr undiff	03/08/79
30.44	BLM test well	3,575.37 tc	320	229.67 tc		03/15/79
32.17.13	BLM test well	3,450.35 tc	100	9.9 tc	Qp	03/15/79
22.33	BLM test well	3,512.52 tc	170	29.65 tc	Tr undiff	03/15/79
31.13	BLM test well	3,549.95 tc	250	135.12 tc		03/15/79
21.27.19.334	Irrigation	3,137.01	320	30.25	Tnsl	02/18/75
25.233	Domestic/Stock	3,141	270	80		05/29/75
29.311	Unused irrigation	3,116.28	236	16.50	Clbd	01/03/62
30.442	Domestic	3,115.48	256	12.78	Cplm	01/10/75
28. 4.413	Stock	3,207	39.5	23.24		12/16/77
4.442	Stock	3,235	185	80.20		12/16/77
12.444	Industrial	3,330	275	205		06/06/73
30.141	Test well	3,181		89.63	Clbd	01/09/75
35.333	Stock	3,160	146.3	136.97	Prfn/Ckbf	10/25/77
29. 2.14	BLM test well	3,422.24 tc	400	273.96		03/15/79
11.421	Observation	3,311		175.0	Pr	03/15/79
12.211	Unused industrial	3,485	>300.0	279.88	Pr	02/23/78
25.423	Domestic (Pue Well)	3,214		67.57	Prc (?)	01/10/79
30.18.330	Observation	3,212	139.3	134.83		03/15/79
18.331	Windmill	3,212	184.0	134.95		10/25/77

Records of wells and test holes in project area, concluded.

Location	Well Status	Altitude (feet)	Depth of Well (ft.)	Depth to Water (ft.)	Aquifer	Date of Measurement
21.30.22.423	Unused	3,180	220 ?	121.32	Pr	03/17/76
31. 3.22	BLM test well	3,519.59 tc	200	140.81	Tr undiff	03/15/79
7.331		3,350	367.0	192.1	Pr	09/14/72
15.33	BLM test well	3,542.06 tc	360	dry		03/15/79
18.411	Windmill	3,310		158 +	Pr	03/17/76
22.27. 1.122	Abandoned stock			0.5		12/15/77
10.333	Irrigation	3,080	169	17.39	Qvf	01/10/75
28. 2.111	Stock	3,154		132.78	Pr	12/04/70
15.323	Stock	3,096	100.8	74.98		12/16/77
16.113	Stock	3,083	151.4	51.92		12/16/77
29.33.214	Observation	3,018	70.3	54.12	Pr	03/15/79
30. 2.232	Industrial	3,210	344.0	183.12		03/16/76
2.431	Industrial	3,180	217.0	135.85		03/16/76
10.1	Observation	3,140		56.78		03/15/79
32.114	Observation	3,024	92.0	31.21		03/15/79
31.15.130	Domestic	3,460		129.0		03/16/76
15.130	Unused	3,460	167.0	133.32		03/16/76
15.131	Unused	3,460	170.0	126.90		10/19/77
23.28. 1.11	BLM test well	3,068.81 tc	300	155.69		03/14/79
29.18.14	BLM test well	2,959.23 tc	35	7.12	Qal	03/13/79
20.33	BLM test well	2,963.21 tc	60	22.88 tc	Prc (?)	03/14/79
26.12	BLM test well	3,030.88 tc	160	107.75	Trdl, Prfn	03/06/79
28.41	BLM test well	2,988.16 tc	100	40.97 tc	Prt	03/14/79
30. 1.33	Stock	3,270		259.01		03/15/79
19.12	Observation	3,043		72		03/15/79
31. 5.324		3,325	231.0	126.40		03/09/76
29.113	Stock	3,333	144.0	138.95		10/19/77

WATER-LEVEL RECORDS OF SELECTED OBSERVATION WELLS

Water-level records of selected observation wells

18.30.32.323
Measured well depth: 161 feet

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Nov 18, 1977	159.65	May 22, 1978	160.22
Dec 5, 1977	158.32	Jun 8, 1978	159.96
Dec 20, 1977	158.72	Jul 17, 1978	160.13
Jan 18, 1978	161.65	Aug 17, 1978	160.09
Feb 3, 1978	159.92	Sep 28, 1978	160.24
Feb 24, 1978	158.37	Dec 14, 1978	160.11
Mar 8, 1978	158.28	Jan 17, 1979	161.24
Mar 30, 1978	158.54	Feb 14, 1979	159.94
May 4, 1978	158.28	Mar 14, 1979	160.21

19.30.25.123
Measured well depth: 42 feet

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Nov 18, 1977	22.73	Jun 8, 1978	22.89
Dec 5, 1977	22.65	Jul 17, 1978	22.02
Dec 20, 1977	22.69	Aug 17, 1978	23.03
Jan 18, 1978	23.37	Sep 27, 1978	23.0
Feb 3, 1978	22.57	Dec 14, 1978	21.67
Feb 23, 1978	22.50	Jan 17, 1979	21.63
Mar 30, 1978	22.47	Feb 14, 1979	21.56
May 4, 1978	22.65	Mar 14, 1979	21.59
May 22, 1978	22.96		

20.30.7.11

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	29.34*	Dec 14, 1978	29.02*
Jun 8, 1978	29.29*	Jan 17, 1979	28.77
Jul 18, 1978	29.21*	Feb 14, 1979	28.72*
Aug 17, 1978	29.45*	Mar 15, 1979	28.69*
Sep 27, 1978	29.35		

* shut down 5 minutes

Water-level records of selected observation wells, continued.

20.30.20.2

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	13.80	Dec 13, 1978	12.89
Jun 8, 1978	14.71	Jan 17, 1979	12.89
Jul 18, 1978	14.05	Feb 13, 1979	12.84
Aug 17, 1978	14.45	Mar 15, 1979	12.88
Sep 27, 1978	13.75		

20.30.29.3

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	101.10	Dec 13, 1978	100.54
Jun 8, 1978	101.18	Jan 17, 1979	100.18
Jul 18, 1978	101.15	Feb 14, 1979	99.89
Aug 17, 1978	101.35	Mar 15, 1979	99.86
Sep 27, 1978	101.49		

20.30.32.4

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Jul 18, 1978	177.62	Jan 17, 1979	175.75
Aug 17, 1978	177.95	Feb 14, 1979	175.13
Sep 27, 1978	177.87	Mar 15, 1979	175.0
Dec 13, 1978	175.52		

21.29.11.4

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	208.50	Sep 26, 1978	208.78
Jun 7, 1978	208.20	Dec 13, 1978	208.02
Jul 18, 1978	208.77	Feb 13, 1979	207.52
Aug 17, 1978	239.33 (?)	Mar 15, 1979	207.72

Water-level records of selected observation wells, continued.

21.30.18.33
Measured well depth: 139.3 feet

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Nov 9, 1977	135.07	Jun 7, 1978	136.25
Dec 5, 1977	135.34	Jul 18, 1978	135.80
Dec 20, 1977	135.77	Aug 17, 1978	135.54
Jan 18, 1978	135.96	Sep 26, 1978	135.45
Feb 3, 1978	136.02	Dec 13, 1978	134.23
Feb 24, 1978	135.95	Jan 17, 1979	134.01
Mar 30, 1978	135.98	Feb 13, 1979	134.87
May 4, 1978	135.96	Mar 15, 1979	134.83
May 23, 1978	136.41		

22.29.33.2
Measured well depth: 70.3 feet

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Nov 9, 1977	54.10	Jun 7, 1978	53.73
Dec 5, 1977	53.17	Jul 19, 1978	53.75
Dec 20, 1977	53.18	Aug 17, 1978	55.44
Jan 18, 1978	53.07	Sep 19, 1978	54.14
Feb 3, 1978	53.65	Dec 13, 1978	52.54
Feb 24, 1978	53.28	Jan 17, 1979	52.47
Mar 30, 1978	53.89	Feb 13, 1979	52.41
May 4, 1978	52.85	Mar 15, 1979	54.12
May 23, 1978	48.5		

22.30.10.1

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	59.96	Dec 13, 1978	56.97
Jun 7, 1978	57.27	Jan 17, 1979	56.17
Jul 18, 1978	57.02	Feb 13, 1979	56.48
Aug 17, 1978	57.05	Mar 15, 1979	56.78
Sep 19, 1978	57.17		

Water-level records of selected observation wells, concluded.

22.30.32.114
Measured well depth: 92.0 feet

Date	Depth to Water (ft)	Date	Depth to Water (ft)
Nov 9, 1977	24.23	Jun 7, 1978	27.60
Dec 5, 1977	29.73	Jul 18, 1978	31.03
Dec 20, 1977	29.74	Aug 16, 1978	30.55
Jan 18, 1978	29.71	Sep 19, 1978	31.14
Feb 3, 1978	29.69	Dec 13, 1978	30.87
Feb 24, 1978	29.65	Jan 16, 1979	31.09
Mar 30, 1978	29.58	Feb 13, 1979	31.57
May 4, 1978	29.52	Mar 15, 1979	31.21
May 23, 1978	31.30		

23.30.1.33

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	258.12	Dec 13, 1978	259.44
Jun 7, 1978	258.42	Jan 16, 1979	257.49
Jul 18, 1978	258.05	Feb 13, 1979	257.35
Aug 16, 1978	258.34	Mar 15, 1979	259.01
Sep 19, 1978	258.17		

23.30.19.1

Date	Depth to Water (ft)	Date	Depth to Water (ft)
May 23, 1978	69.99	Dec 13, 1978	69.40
Jun 7, 1978	69.93	Feb 13, 1979	69.06
Jul 18, 1978	69.50	Mar 15, 1979	72.0 ±
Sep 19, 1978	70.02		

RAIN GAGE NETWORK RECORDS

Rain Gage Network Records

18.29.26.1

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 26, 1978	+ 6	Jan 17, 1979	0.40
Oct 20, 1978	0.6	Feb 13, 1979	.40
Nov 16, 1978	2.90	Mar 15, 1979	.35
Dec 13, 1978	.4		

Aug 28, 1978-Mar 15, 1979 Total = +11.05

19.30.8.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 26, 1978	+ 6	Jan 17, 1979	0.45
Oct 20, 1978	.3	Feb 13, 1979	.20
Nov 16, 1978	2.60	Mar 15, 1979	.25
Dec 13, 1978	.35		

Aug 28, 1978-Mar 15, 1979 Total = +10.15

19.30.21.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 26, 1978	+ 6	Jan 17, 1979	0.50
Oct 20, 1978	.1	Feb 13, 1979	.35
Nov 16, 1978	3.40	Mar 15, 1979	.15
Dec 13, 1978	.35		

Aug 28, 1978-Mar 15, 1979 Total = +10.85

Rain gage network records, continued.

19.30.34.4

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	0.6	Dec 13, 1978	0.4
Sept 26, 1978	+ 6	Jan 17, 1979	.60
Oct 20, 1978	.3	Feb 13, 1979	.25
Nov 16, 1978	3.60	Mar 15, 1979	.075
Aug 28, 1978-Mar 15, 1979 Total = +11.825			

19.31.15.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	0.8	Dec 13, 1978	0.4
Sept 26, 1978	+ 6	Jan 17, 1979	.50
Oct 20, 1978	.1	Feb 13, 1979	.30
Nov 16, 1978	3.85	Mar 15, 1979	gage missing
Aug 28, 1978-Mar 15, 1979 Total = +11.95			

19.31.28.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	0.8	Dec 13, 1978	0.35
Sept 26, 1978	+ 6	Jan 17, 1979	.40
Oct 20, 1978	.2	Feb 13, 1979	.40
Nov 16, 1978	3.60	Mar 15, 1979	.05
Aug 28, 1978-Mar 15, 1979 Total = +11.8			

19.32.32.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.2	Dec 13, 1978	0.3
Sept 26, 1978	+ 6	Jan 17, 1979	.35
Oct 20, 1978	unmeasureable amount	Feb 13, 1979	.35
Nov 16, 1978	+ 6	Mar 15, 1979	0
Aug 28, 1978-Mar 15, 1979 Total = +14.2			

Rain gage network records, continued.

20.30.21.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.5	Dec 13, 1978	0.35
Sept 26, 1978	+ 6	Jan 17, 1979	.40
Oct 20, 1978	unmeasureable amount	Feb 13, 1979	.40
Nov 16, 1978	5.00	Mar 15, 1979	0

Aug 28, 1978-Mar 15, 1979 Total = +13.65

20.30.31.1

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	1.3	Dec 13, 1978	0.35
Sept 20, 1978	1.4	Jan 17, 1979	.50
Sept 26, 1978	+ 6	Feb 13, 1979	.40
Oct 20, 1978	unmeasureable amount	Mar 15, 1979	0
Nov 16, 1978	4.65		

Aug 28, 1978-Mar 15, 1979 Total = +14.6

20.30.33.4

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	2.4	Dec 13, 1978	0.3
Sept 26, 1978	+ 6	Jan 17, 1979	.40
Oct 20, 1978	.15	Feb 13, 1979	.40
Nov 16, 1978	5.35	Mar 15, 1979	0

Aug 28, 1978-Mar 15, 1979 Total = +15

20.31.33.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.0	Dec 13, 1978	0.35
Sept 26, 1978	+ 6	Jan 17, 1979	.40
Oct 20, 1978	.1	Feb 13, 1979	.35
Nov 16, 1978	5.55	Mar 15, 1979	0

Aug 28, 1978-Mar 15, 1979 Total = 13.75

Rain gage network records, continued.

20.31.36.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	2.5	Dec 13, 1978	0.3
Sept 26, 1978	+ 6	Jan 17, 1979	.30
Oct 20, 1978	.1	Feb 13, 1979	.45
Nov 16, 1978	4.20	Mar 15, 1979	0

Aug 28, 1978-Mar 15, 1979 Total = +13.85

20.32.32.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.8	Dec 13, 1978	0.3
Sept 26, 1978	+ 6	Jan 17, 1979	.45
Oct 20, 1978	.3	Feb 13, 1979	.25
Nov 16, 1978	3.80	Mar 15, 1979	0

Aug 28, 1978-Mar 15, 1979 Total = +12.9

21.29.12.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	0.6	Dec 13, 1978	0.3
Sept 26, 1978	+ 6	Jan 17, 1979	.35
Oct 20, 1978	unmeasureable amount	Feb 13, 1979	.55
Nov 16, 1978	4.70	Mar 15, 1979	.05

Aug 28, 1978-Mar 15, 1979 Total = +12.55

21.29.25.4

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.2	Dec 13, 1978	gage gone
Sept 26, 1978	+ 6	Jan 17, 1979	gage installed Jan 17, 1979
Oct 20, 1978	.2	Feb 13, 1979	0.45
Nov 16, 1978	3.30	Mar 15, 1979	gage gone (new fence)

Aug 28, 1978-Mar 15, 1979 Total = +11.15

Rain gage network records, continued.

21.30.6.1

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	2.1	Dec 13, 1978	0.35
Sept 26, 1978	+ 6	Jan 17, 1979	.35
Oct 20, 1978	.3	Feb 13, 1979	.45
Nov 16, 1978	+ 6	Mar 15, 1979	.05

Aug 28, 1978-Mar 15, 1979 Total = +15.6

22.29.1.1

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 20, 1978	1.2	Dec 13, 1978	0.35
Sept 26, 1978	+ 6	Jan 17, 1979	.40
Oct 20, 1978	.2	Feb 13, 1979	.45
Nov 16, 1978	3.10	Mar 15, 1979	.05

Aug 28, 1978-Mar 15, 1979 Total = +11.75

22.29.15.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	0.8	Dec 13, 1978	gage gone
Sept 20, 1978	.8	Jan 17, 1979	installed gage Jan 17, 1979
Sept 26, 1978	+ 6	Feb 13, 1979	0.50
Oct 20, 1978	.2	Mar 15, 1979	
Nov 16, 1978	2.75		

Aug 28, 1978-Mar 15, 1979 Total = +11.05

22.30.8.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	1.0	Dec 13, 1978	unmeasureable
Sept 20, 1978	1.0	Jan 17, 1979	0.60
Sept 26, 1978	+ 6	Feb 13, 1979	.10 (gage tilted)
Oct 20, 1978	.1	Mar 15, 1979	.10
Nov 16, 1978	2.85		

Aug 28, 1978-Mar 15, 1979 Total = +11.75

Rain gage network records, continued.

22.30.10.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	1.6	Dec 13, 1978	0.3
Sept 20, 1978	1.5	Jan 17, 1979	.45
Sept 26, 1978	+ 6	Feb 13, 1979	.35
Oct 20, 1978	.1	Mar 15, 1979	0
Nov 16, 1978	3.00		

Aug 28, 1978-Mar 15, 1979 Total = +13.3

23.28.12.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	1.1	Dec 13, 1978	0.35
Sept 20, 1978	1.1	Jan 17, 1979	.50
Sept 26, 1978	+ 6	Feb 13, 1979	.65
Oct 20, 1978	unmeasureable amount	Mar 15, 1979	.10
Nov 16, 1978	4.35		

Aug 28, 1978-Mar 15, 1979 Total = +14.15

23.29.1.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	0.35	Dec 13, 1978	0.25
Sept 20, 1978	.3	Jan 17, 1979	.40
Sept 26, 1978	+ 6	Feb 13, 1979	.45
Oct 20, 1978	.2	Mar 15, 1979	0
Nov 16, 1978	2.40		

Aug 28, 1978-Mar 15, 1979 Total = +10.35

23.29.5.2

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	0.45	Dec 13, 1978	0.4
Sept 20, 1978	.4	Jan 17, 1979	.45
Sept 26, 1978	+ 6	Feb 13, 1979	.50
Oct 20, 1978	.1	Mar 15, 1979	0
Nov 16, 1978	3.50		

Aug 28, 1978-Mar 15, 1979 Total = +11.8

Rain gage network records, concluded.

23.30.2.3

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	2.3	Dec 13, 1978	0.3
Sept 20, 1978	2.3	Jan 16, 1979	.45
Sept 26, 1978	+ 6	Feb 13, 1979	.25
Oct 20, 1978	.2	Mar 15, 1979	.05
Nov 16, 1978	3.50		
Aug 28, 1978-Mar 15, 1979 Total = +15.35			

23.30.5.4

Date	Precipitation (in inches)	Date	Precipitation (in inches)
Sept 19, 1978	0.5	Dec 13, 1978	0.3
Sept 20, 1978	.5	Jan 16, 1979	.45
Sept 26, 1978	+ 6	Feb 13, 1979	.25
Oct 20, 1978	.2	Mar 15, 1979	.05
Nov 16, 1978	3.15		
Aug 28, 1978-Mar 15, 1979 Total = +11.4			

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Stenocraft®
Clasp
8¼ x 11¼ – #81

R. 27 E.
R. 28 E.
R. 29 E.
R. 30 E.
T. 19 S.
T. 20 S.
T. 21 S.
3276
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3417
3404
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3238
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3038
3175
3181
3154
3150
3125
3100
3075
3107
3091
3225
Mullman Ranch
Old City
North Williams Ranch
Williams Hollow
West Well
Rattlesnake Draw
Benson Ranch
Millman South Well
Angel Draw
Babbs Ranch
Seaton Draw
Salado Flat
Murray West Well
Murray Ranch
Fenton Ranch
Lake Avalon
CARLSBAD NATIONAL WILDLIFE REFUGE
Quahada Ridge
Sand Point
Joe Lusk East Well
Chimney Draw
Fenton Draw
Lone Tree Draw
Penmilha
BURTON FLAT
DELAWARE MOUNTAINS
CLAYTON
U.S. POTASH RESERVE
ATCHISON TOPEKA AND SANTA FE
104°18'
32°48'
530000 FEET
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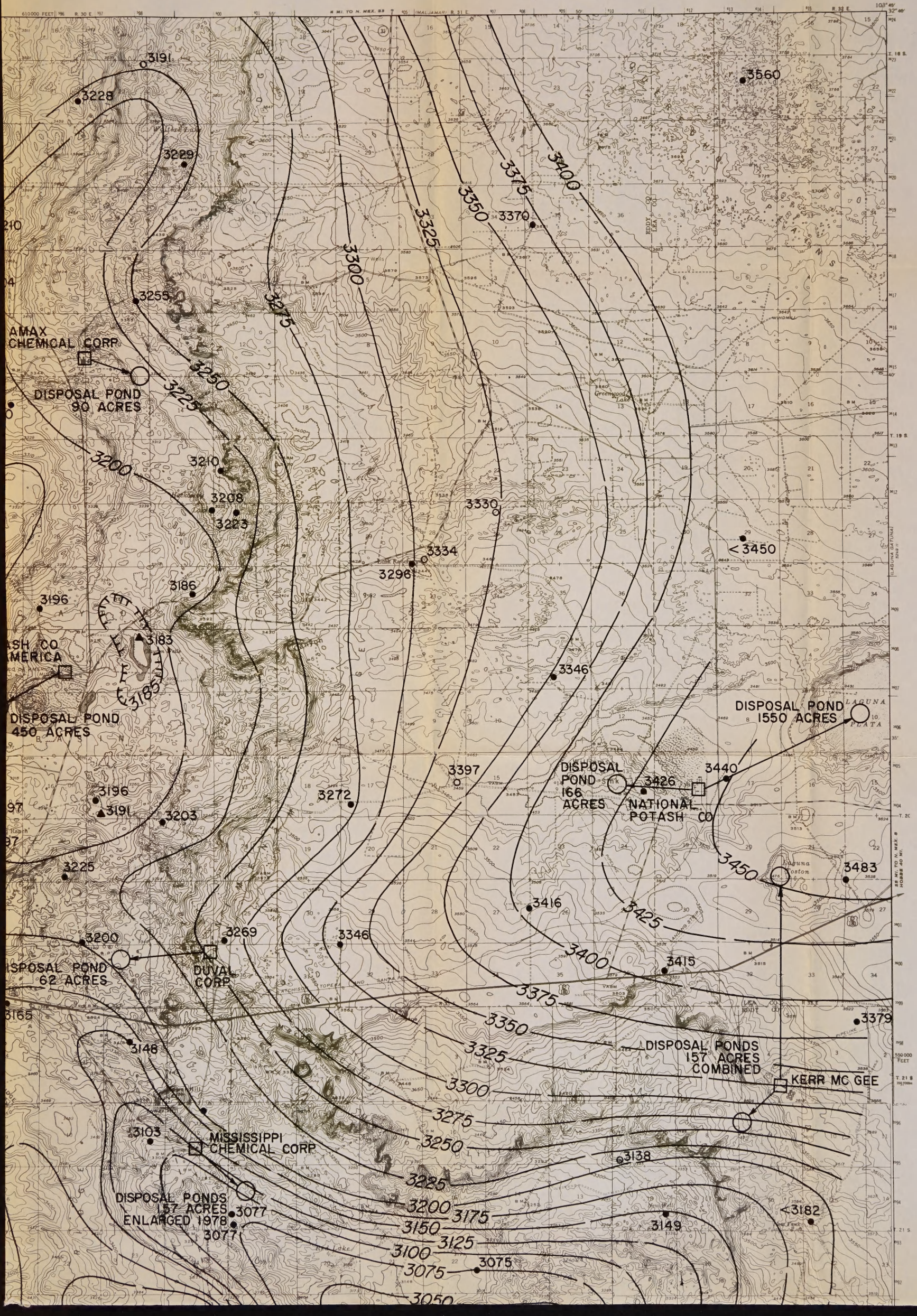
540000 FEET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AMAX CHEMICAL CORP
DISPOSAL POND 90 ACRES
DISPOSAL POND 450 ACRES
DISPOSAL POND 62 ACRES
DUVAL CORP
DISPOSAL POND 166 ACRES
NATIONAL POTASH CO
DISPOSAL POND 1550 ACRES
DISPOSAL PONDS 157 ACRES COMBINED
KERR MC GEE
MISSISSIPPI CHEMICAL CORP
DISPOSAL PONDS 157 ACRES ENLARGED 1978
EDDY CO
LEA CO
LAGUNA PLATA
Laguna Toston
Green wood Lake
Lusk Ranch
Wells
Windmill
Pipeline
T. 19 S.
T. 20
T. 21 S.
610000 FEET
550 000 FEET
R. 30 E.
R. 31 E.
R. 32 E.
8 MI. TO N. MEX. 33
25 MI. TO N. MEX. 8 HOBBS 40 MI.

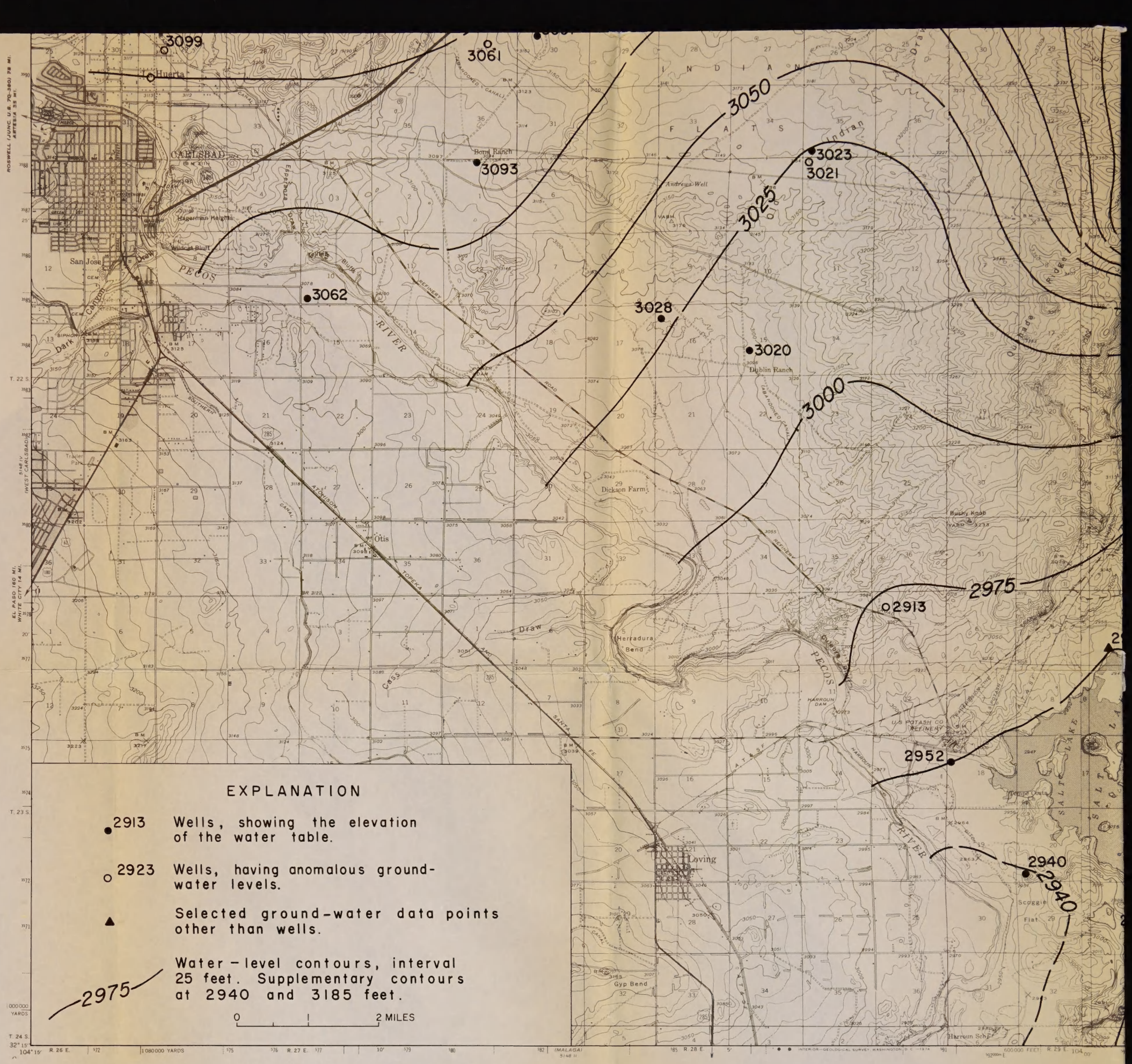

PLATE 1.-- WATER-TABLE CONTOUR MAP (

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Potash area,

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